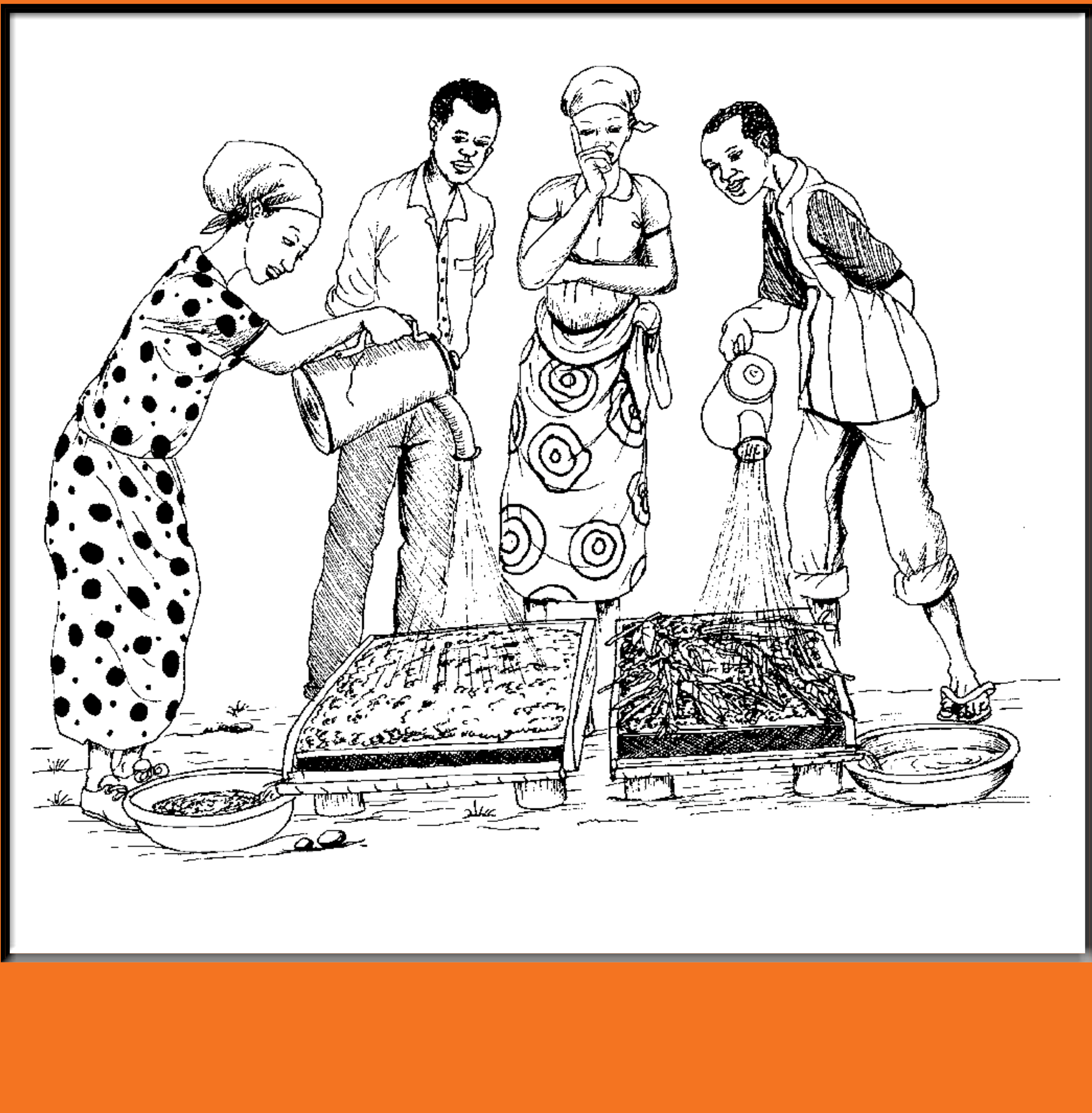
Food and Agriculture Organization
of the United Nations

Discovery-based learning in land and water management

A practical guide for farmer field schools



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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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Preface

The Land and Water Division of the Food and Agriculture Organization of the United Nations (FAO) has supported the capacity building process on land and water management through farmer field schools in eastern and southern Africa since 2001. Various partners that are mentioned in the list of contributors have largely carried out the fieldwork that lies at the basis of this publication. Without their inputs, this guide for farmer field school facilitators, trainers and extension services and a wider range of development practitioners, would not have been possible.

Farmer field schools have proven a successful approach for community based learning, education and extension around the world. Originated in Asia in integrated pest management they have been expanded over the years across the globe. At the same time farmer field schools have been adapted to different contexts and technical areas to help farmers in making their farming systems more productive and sustainable. FAO supported the development and publication of this field guide as part of a pilot programme to apply the farmer field school approach for land and water management issues in Africa with development partners.

This publication is not exhaustive. Rather, it presents a collection of easily readable, illustrated modules that will guide trainers and facilitators in introducing and promoting improved land and water management through farmer field schools. We encourage a wide range of field partners (extension, research, NGOs, community based organizations, farmers' associations, etc.) to use the guide in their work with farmers and communities. This will serve to test and improve the materials and the discovery learning process within farmer field schools. We welcome continuous use and adaptation of this guide supported by FAO's Plant Production and Protection Division, Land and Water Division and Decentralized Offices worldwide.

We believe this will be a very useful reference for the farmer field school trainers and facilitators in Eastern and Southern Africa, and may also serve as a basis for adaptation to other farming systems around the world. Besides this guide, FAO will be pleased to provide advice for effective use and wider promotion and application of farmer field school approaches for land and water management as part of sustainable food and agricultural systems, by service providers, project partners and national programmes. This is expected to lead to a wide adaptation and scaling out of farmer-driven learning processes, suitable practices and integrated landscape approaches for achieving sustainable livelihoods and generating ecosystem services.

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- The participants of the Rome and Njoro writeshops (see the list of contributors on the next page) who contributed technical expertise and field experiences.

Sincere thanks for their valuable contributions also go to:

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- the Crop Management Resource Training Centre of Egerton University in Njoro, Kenya which hosted the writeshop in Kenya
- the many farmers, farmer field school facilitators, extension workers, NGO staff and researchers, whose knowledge and experiences are reflected in this guide;
- Paul Mundy, freelance editor, who contributed greatly in making the manual readable and user- friendly.

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Introduction

Participatory approaches are the key to enabling farmer groups and communities to address their farming problems and develop viable and sustainable farm livelihood systems. There is a lot of evidence of the benefits of empowering farmer's groups and communities through participatory technology development and farmer innovation. The farmer field school approach has been very successful, initially for farmer experiential learning on integrated pest and production management and, over the years, including livestock/ pastoral and soil and water management issues for addressing degradation and declining productivity of farming systems. It helps farmers understand the ecology and principles behind managing natural resources, pests and diseases and human-environmental interactions. It also provides an excellent way to help them adapt their behavior and practices to cope with change (climate, markets, land and water availability…) on their farms and in the surrounding area.

Various development efforts have shown the need to address a range of issues in promoting FFS and sustainable agriculture such as:

- Using an integrated perspective at farm and landscape level to halt land productivity decline and natural resources degradation and sustain livelihoods.
- Promoting a wide range of land and water management practices to optimize the local environment for crop growth and for associated animal and forest production.
- Promoting agricultural biodiversity in terms of diverse farms and wider ecosystem. This includes the plant species and varieties and the animal breeds and the associated biodiversity such as: habitat for pollinators and for beneficial predators; soil biodiversity which maintains a healthy, fertile soil, as well as, soil-plant-water interactions that contribute to nutrient cycling and replenishment of soil organic matter.
- Maintaining a good vegetation cover and soil litter for increasing storage of carbon. This includes use of perennials for permanent cover and deep rooting, and minimizing burning to reduce losses into the air. This also increases the soil organic matter and enhances rainwater capture and infiltration into the soil thereby reducing loss of water by surface runoff.
- Educating and raising awareness of farmers and local partners (research, NGO, local government), communities and other civil society organizations.
- Creating policies and institutions that support sustainable agricultural development – both more productive and environmentally friendly – and encouraging young people to become "smart" farmers.
- Finding ways to help farmers and communities to cope with labour shortages and building on valuable local and indigenous knowledge and innovations as well as modern science.

FAO and its partners have developed this guide to support various organizations in the region that identified the need for information materials to improve their field-level capacities in land and water management for smallholder farming. In particular, for providing technical support to service providers (farmer group facilitators, extension/advisory services staff, NGOs, etc.). Information materials are also needed to illustrate improved land management practices that farmers can test so they can identify and adapt the best options for their own situations.

Many organizations are involved in promoting land and water management through farmer field schools in Eastern and Southern Africa. A good number of them have contributed to this guide, which reflects their collective experience. However, this guide should not be seen as exhaustive but as a stepping stone towards accelerating work with farmers' groups and communities and further developing approaches, practical techniques, adapted training materials and processes for specific farming situations.

In putting together this guide, the contributors chose the most important and relevant concepts, techniques and learning exercises, largely based on experiences of farming communities in sub-humid regions that face severe nutrient mining and erratic rainfall. As and when gaps are identified partners are encouraged to develop new exercises or modules, through practical work with groups of farmers and service providers, and to make these available. Positive experiences generated through use of the guide should be disseminated through networking, field days and other events for enabling wider uptake and support of policy makers.

Producing this guide

This guide is a product of more than three years of intensive consultations with staff and resource persons from various projects and institutions. The final product was compiled through an intensive, participatory "writeshop", followed by a certain amount of writing and editing. The overall organization and technical management was guided by the Land and Water Division of FAO, supported by the Africa Regional Office of the International Institute for Rural Reconstruction. A large part of this guide is based on activities and projects conducted by FAO and its partners on piloting farmer field schools for improved land and water management and conservation agriculture approaches in Kenya (Mwingi, Kitui, Nakuru, Kiambu and Mbeere), Tanzania (Bukoba) and Uganda (Mbale, Pallisa, Tororo and Busia).

About this field guide

This book is a practical field guide for facilitators of farmer field schools, trainers and project staff. It can also be used by national agricultural development programmes and others to strengthen the empowerment of farmers, in training on land and water management, and as a guide to discovery-based learning in land and water management.

In this book you will find technical information and many discovery-based practical exercises and examples of field studies. You can use it in various ways: to train trainers or facilitators on land and water management, to guide groups of farmers through field studies, or to help them experiment with and adapt technologies.

Many of the practical exercises in this book have been field-tested in one or more countries in Africa and Asia. These exercises come from various sources. Some were developed by projects and institutions, some by farmer field school trainers, and some by the participants of the "writeshops" which compiled this book.

Learning modules

This book has 16 modules, each of which contains technical information and a series of practical exercises for training and field experimentation.

Each module and each exercise stands on its own, so you can choose those that suit your particular situation. You should choose your starting point and sequence of modules carefully, in response to the farming situation, agro-ecological zone and the farmers' interests in the area.

Modules 1–3 deal with the farmer field school process as it is used in land and water management.

- ***Module 1*** *Discovery-based learning*: introduction to the farmer field school approach in land and water management.
- ***Module 2*** *Improving land management*: identification of opportunities and training of farmer groups for improved land and water management at both farm and community level.
- ***Module 3*** *Innovation and experiments*: use of farmer innovations in farmer field schools, and introduction of experimental learning and participatory technology development.

Modules 4–14 cover technical topics. They are geared to improved understanding and management practices of soil, water, crop and livestock resources and the agro-ecosystem.

- ***Module 4*** *Knowing your soil*: understanding the characteristics and functions of soil and its effects on soil management and productivity.
- ***Module 5*** *Using organic materials*: organic resource management.
- ***Module 6*** *Encouraging soil life*: the importance of soil life and enhancement of soil biological activity.
- ***Module 7*** *Managing plant nutrients*: farm nutrient management improvement.
- ***Module 8*** *Conservation agriculture*: reduced tillage, increased soil cover and improved crop rotations.

- ***Module 9*** *Managing livestock*: how to make better use of livestock.
- ***Module 10*** *Managing rainwater*
- ***Module 11*** *Harvesting water for crops*
- ***Module 12*** *Harvesting water for people and livestock*
- ***Module 13*** *Managing weeds*.
- ***Module 14*** *Managing biodiversity*: increased farm diversity to raise food security, use resources optimally, and improve livelihoods.

The last two modules deal with socio-economic and project management issues.

- ***Module 15*** *Farm management, marketing and diversification*.
- ***Module 16*** *Assessing impacts, learning lessons*: monitoring farmer field schools and impact assessment.

Each of the 16 modules covers a separate topic. But in reality, these topics are not distinct or separable: the challenge is to help the farmers to learn the concepts through the training modules and to then apply and adapt the practices in an integrated way that suits their changing farm and household situation. For example, the modules on organic resources (▶ *Module 5*), plant nutrients (▶ *Module 7*), livestock (▶ *Module 9*) and soil moisture (▶ *Module 10*) all look at different aspects that should be combined in farmers' fields – i.e., integrated plant nutrient management. You may find it a major challenge to gear up from the initial stage of helping farmers, through experiments, to learn about these topics, to the next stage of guiding them to diversify their farms and adopt an integrated farm–livelihood systems approach. This may require support of technical/research partners.

How to use this guide?

The modules provide technical and practical reference materials. They give background information and describe exercises and studies that can be conducted in the field to improve understanding of the topic and as decision-making tools during training of trainers, in farmers' farmer field schools, and in action research. The information is tailored for farming systems and agro-ecological zones in eastern and southern Africa. But it is generic in nature and can be widely used and adapted elsewhere.

This handbook is intended as an inspirational guide that summarizes technical information and land and water management principles and practices in eastern and southern Africa. It aims to encourage discovery-based training and experiments on land and water management worldwide.

It is not possible to become an expert on land and water management just by reading this guide. This book provides the "how to"; the field remains the main learning base. This is why the practical exercises and experiments are an essential part of the learning process.

More information on land and water management and farmer field schools:

- *FAO: www.fao.org/nr/dep/nrl_en.htm*

How to use the exercises?

You can use the practical exercises described in this guide for training farmer field school facilitators and in farmer field schools themselves. Make sure to tailor them to fit the specific conditions where you are working. Avoid using them as a "recipe" but be innovative and responsive. Treat them as a source of inspiration – of ideas that you can adapt to local needs.

We welcome any contributions of additional modules or adaptations to existing modules or exercises that have been developed and tested in specific farming contexts. We will be pleased to consider these for inclusion in future versions of this guide.

Format of exercises

Each of the exercises follows a standard format:

- **Title and introduction:** The name and a short description of the exercise.
- **Learning objectives:** What the learners can expect to discover from the exercise.
- **Timing:** Guidance on when to use the exercise (e.g., during the dry season), what might be happening in the study field, and the type of experience a farmer field school group needs to have before starting.
- **Preparation:** What to do before carrying out the exercise.
- **Time:** How long the farmer field school is likely to need to carry out the exercise; any additional time inputs needed outside the farmer field school meetings.
- **Materials:** What equipment and supplies are needed.
- **Steps:** How to go about the exercise, and build experimental capacity by the farmer groups.
- **Questions:** Ideas to stimulate discussion and further exploration by your farmer field school groups.
- **Notes:** Additional aspects to think of or ways to use or adapt the exercise.

Preparatory workshops

Two preparatory workshops were held to determine the scope of the guide, its intended audience, the topics to cover, and the institutions and individuals with relevant experience and expertise. The first workshop, in May 2002 in Kampala, Uganda, identified a range of topics, institutions and individuals, and reached agreements about partner contributions and assignments. A second preparatory workshop was held in May 2004 at FAO headquarters in Rome, Italy. It reviewed the intended audience, determined the major sections of the guide, and outlined the contents of each module. The participants also identified institutions and individuals to draft manuscripts on specific topics and to present them at the production writeshop.

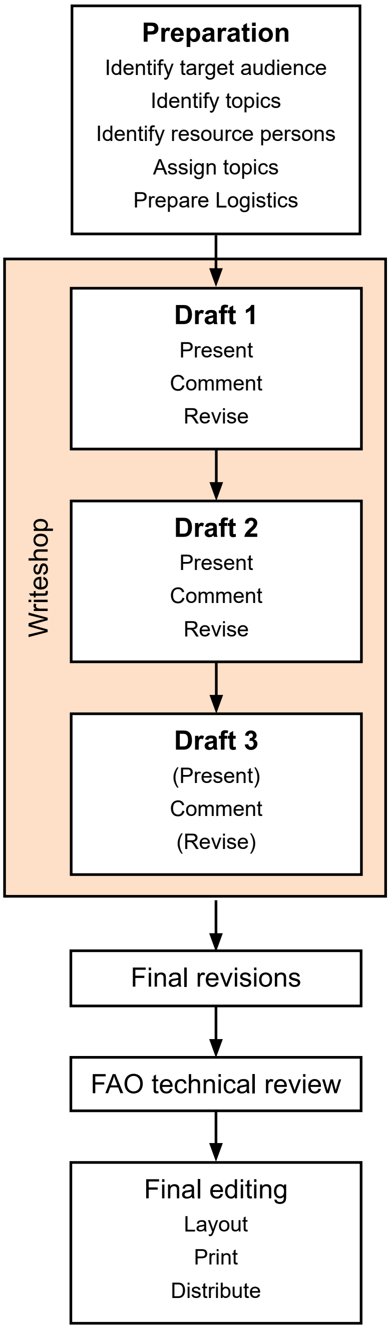


Figure 0.1. Outline of the writeshop process

Production writeshop

The guide itself is the product of a six-day intensive writeshop at Egerton College, Njoro, Kenya, on 24–31 October 2004. The writeshop involved resource persons from pilot projects and partner organizations with practical experience of farmer field schools in land and water management, field practitioners and farmer field school facilitators, as well as artists, editors and desktop-publishing specialists. During the writeshop, the authors presented their draft manuscripts of each module (if a module author was unable to attend, another participant familiar with the topic presented the manuscript). Copies of each draft were also provided to all other participants, who provided comments and suggested revisions. During each presentation the editor took notes of the discussions, and passed these on to the author. After the presentation, each author worked with the other participants to incorporate their comments. Meanwhile, an artist made drawings to illustrate the text.

A revised version of each module was then presented to a selected group of reviewers, using a beamer or transparencies. Again, the audience made comments and suggested revisions. This process was repeated up to four times until the manuscript was agreed upon.

After the writeshop, FAO reviewed the drafts with in some cases substantial rewriting to ensure they were consistent and technically correct, and to avoid gaps and duplication. The drafts were then edited and shortened considerably to make them fit in a book of manageable length. The artwork was finalized, and the publication was laid out and printed in the form you see before you.

Through this process, some of the original manuscripts were revised substantially to integrate information or ideas from other sources. As a result, a single section in this book may contain information from many different contributors. That means it is not possible to label a particular section as the work of a particular author. The "authors" of the book are thus the participants of the Rome workshop and Njoro writeshop participants and contributors who are listed at the start of this book.

Why the writeshop process?

The writeshop process was pioneered by the International Institute of Rural Reconstruction at its headquarters in the Philippines, and has been used by the Institute's Africa office to produce manuals on subjects as diverse as ethnoveterinary medicine, sustainable agriculture, public awareness and dryland farming. This was the first time that the Institute used the approach in direct collaboration with FAO; but has since inspired further collaboration in training materials development and writeshop/workshop facilitation.

The writeshop approach has several advantages over conventional methods of producing a guide. It speeds up the production, taking advantage of many different participants and staff, who provide their own knowledge and expertise to each story. The process of writing, collecting comments, revising and illustrating the book takes place at the same time, considerably facilitating the often-difficult process of participatory development of adapted training materials and subsequent editing and publishing.

In addition, the writeshop brings together a large number of people from different countries and various institutions. Each has his or her own perspectives and experiences. The discussions and exchange of ideas, both as part of the writeshop sessions and during the breaks, are very rich and valuable.

The relationships and networks forged during a writeshop will continue long into the future, promoting the application and further adaptation of these materials for farmer learning and empowerment and sustainable development.

Module 1. Discovery-based learning

Overview of the farmer field school approach

Farmers face many challenges as they struggle to feed their families and improve their lives. To increase their agricultural productivity and improve food security, farmers must be able to choose, adapt and apply practices that are productive, profitable and sustainable. They should be able to blend their own experience and innovations in managing their limited resources with new methods and advice from outside.

Extension agencies and other service providers increasingly realize they must listen to what farmers say. Farmers do not want to be taught a set of prescribed techniques that may not fit their needs. Instead, they want assistance to enhance their knowledge and their capacity to decide how to best manage their resources and adapt to change. Before they start using a new technology, they want to see whether it works and what it can offer for their own farms and households.

The farmer field school approach responds to these desires. It is a partnership between farmers, extension providers, the private sector and researchers. Each of these actors taps the others' experiences in a learning process centred on the farmers.

The emphasis of the approach is on empowering farmers to make reasoned decisions in their own fields and farms. Problems are seen as challenges, and facilitators and farmers learn to identify opportunities to tackle any problem they might encounter in the field through a process of experimental learning and adaptation. They use agro-ecosystem analysis (► *Module 3 Innovation and experiments*) to monitor basic production and ecological processes, and to observe and compare the impacts of various practices in the field. Supported by extension and research, the farmers discuss and analyse, identify which practices are most productive in terms of land, water, labour, inputs and income, and ensure they use the natural resources on the farm and in the community area in a sustainable and efficient way.

Learning objectives

After studying this module, you should be able to:

Understand the basic principles of the farmer field school approach.

Understand how to establish and run a farmer field school. This should be centred on the study plot for learning together, and backed up by practical advice on how to use resources better on their farms and in the surrounding area, as in, for example, water harvesting.

Understand the specific requirements needed to run farmer field schools on land- and water-related topics.

Plan and implement farmer field schools on land and water management, and adapt the process to specific agro-ecosystems.

Identify key entry points that interest farmers and offer them clear benefits in improving their land and water management practices.

Use a step-by-step learning process, gradually bringing in new subjects to strengthen the farmers' knowledge and to progress towards a more integrated resources management.

Show how improved soil and water management and diversified farms help improve production and food security, raise income, reduce risk, restore degraded soils, and promote sustainable and healthy ecosystems.

Overview of the farmer field school approach

A farmer field school is a method that enables a group of farmers – male and female, young and old – to learn and to share experiences with each other. The farmers' own fields provide the "classroom" where the farmer field school members, guided by a trained facilitator, discover and understand their common problems and find solutions to them. In the process, farmers take active roles in developing and applying strategies aimed at improving their resources management and livelihoods.

The informal setting empowers farmers to be their own technical experts on major aspects of farming. The group usually consists of 25–30 farmers who agree to meet frequently with a trained facilitator to discover solutions to problems they have jointly identified during a series of problem identification exercises (► *Module 2 Improving land management*). A farmer field school may last one or more seasons, depending on what the group chooses to study.

Box 1.1. Features of a farmer field school

- Farmer participation (from problem analysis, to study plot design, monitoring for decision making and evaluation)
- Based on hands-on experience sharing.
- Centred on capacity building and empowerment.
- Ownership of the process by stakeholders.
- Entails a whole production cycle (livestock, annual and perennial crops or even extended over a crop rotation).
- Location-specific.
- Group-based.

Farmer field schools are not a new idea; rather a mix of various ideas or concepts that have been neglected by the conventional extension system of top-down message delivery. The attitude of extension providers and how they relate to farmers and herders is vital for wide adoption of better practices. The farmer field school features (► *Box 1.1*) all lead towards a change in the farmer–facilitator relationship.

Objectives of farmer field schools

Farmer field schools enable farmers to work together to study and solve problems they face. They aim to:

- Empower farmers with knowledge and skills in farming.
- Sharpen their ability to make critical and informed decisions to make their farming profitable and sustainable.
- Sensitize them in new ways of thinking and solving problems.
- Facilitate them to organize themselves and their communities.

Financing

The costs of running a farmer field school usually include farm tools and inputs for the trial plot, stationery for the learning sessions, and funds to pay service providers such as extension staff. The farmer field school also needs some land for study plots and a place to meet (usually provided for free by group members or local leaders).

The way farmer field schools are financed influences their sustainability. Various financing models – self-financing groups, grant systems, loans and revolving funds, savings and micro-financing – have been tested. The current trend is self-financing schools. If groups are coherent and well-facilitated, it is possible to progress over time from completely donor-financed, to partially donor-financed, to self-financing farmer field schools.

Activities that can help to achieve the goal of self-financing include:

- Group savings
- Commercial group enterprises
- Volunteerism and cooperation
- Borrowing from micro finance institutions
- Taking risks
- Market-oriented farmer groups
- Negotiation (with service providers and private sector) for better terms for inputs, farm gate prices and advisory services
- Supportive policies
- Synergies created among farmer field school members

Figure 1.1. "People remember: 20% of what they hear, 40% of what they see, 80% of what they discover themselves"

Basic principles

The following basic principles form the basis of the farmer field school approach:

Farmers are experts

Farmers carry out comparative studies on subjects they choose, so becoming local experts in the topics they study, and in experimenting and adapting. Many are able to give support and advice to other farmers, so acting as farmer-facilitators.

The field is the learning ground

All learning is field-based. The "field" may be a farm plot, or a particular location such as a farm, dairy unit, poultry unit, greenhouse, grazing ground or soil pit. This is where the group learns. Working in small subgroups, the farmers collect data, analyse it, decide what to do, and present their decisions to the other farmers in the farmer field school for discussion, questioning and refinement.

The extension worker is a facilitator

The extension worker acts as a facilitator rather than a conventional teacher. His or her task is to guide the learning processes, fill in the missing gaps, and gradually hand over responsibility to the group.

The training follows the seasonal cycle

For annual crops, the season lasts from land preparation to harvesting. For fodder production it also includes the dry season, so the farmers can evaluate the quantity and quality of fodder at a time of year when feeds are commonly in short supply. For tree production, and conservation measures such as hedgerows and grass strips, training must continue over several years for the farmers to see the full range of costs and benefits.

Learner-centred learning materials

Farmers generate their own learning materials, from drawings of what they see, to the field trials themselves. These materials are cheap and reflect local conditions.

Group dynamics/team building

Training also includes communication skills, problem solving, leadership development and discussion methods.

Adult learning

The success of a farmer field school largely depends on the ability of the facilitator. He or she must recognize that farmers have knowledge gained from many years of farming experience. Here are six principles of adult learning to follow:

Learning occurs inside the learner, and is activated by the learner. The farmer field school facilitator recognizes the farmers' vast wealth of knowledge, and blends it with relevant technologies from elsewhere. People learn if they can explore and discover meaning for themselves.

Learning is a discovery of meaning and relevance. People more readily internalize and implement ideas that are relevant to their needs and problems.

Figure 1.2. The extension worker is a facilitator, not a teacher

Box 1.2. What do farmers and facilitators say about farmer field schools?

"Farmers considered me as a policeman enforcing the Agricultural Act before the introduction of the farmer field school methodology. Now with this approach I am liked and welcomed in their homes as one of them." – Ngeti, an extension facilitator from Taita District, Coast Province, Kenya (2004).

"The farmer field school programme has created unity in the people at grassroot level." – Juma Francis, Chairman of Bungundihira farmer-run farmer field school in Dabani, Busia District, Uganda (2001).

"Never in life had we ever thought of trapping rainwater for farming, but now we realize the importance of water harvesting after the exchange visit to Okidoi Farmer field school." – Ekochu Joseph, member of Arapai Farmer field school in Soroti District, Uganda (2002).

"In the past we were taught what to do, today we learn by experimenting." – Mr. L Nkomo, a farmer from Tsholotsho District in Matabeleland Province, Zimbabwe (2003).

Figure 1.3. In a field school, farmers learn by doing

For example, it is easier to explain drip irrigation to farmers who already do bucket irrigation, than to a pastoralist.

Learning (behavioural change) is a consequence of experience. Farmers' experience guides them to do certain things – for example, to accept or reject a new practice. People do not change their behaviour just because someone tells them what to do.

Learning is a cooperative process. Two heads are better than one. People enjoy working by themselves, but they also enjoy working together. Group dynamics and team building exercises encourage them to collaborate and to learn as a group.

Learning is sometimes painful. Change often means giving up old, comfortable ways of thinking. It can be uncomfortable to share ideas openly, to put ones ideas under the scrutiny of a group, and to confront other people. Experience makes this easier.

One of the richest resources for learning is the learner him- or herself. When so much emphasis is on instructional media, books and speakers as resources for learning, we tend to overlook the richest source of all – the learner him- or herself. Each person has a wide range of experiences, ideas, feelings and attitudes. These are a rich source of material for problem solving and learning.

Facilitated processes

A facilitator puts these principles into practice in a farmer field school. He or she:

- Guides the process of discovery-based learning.
- Ensures an effective flow of information within the group so that participants can share information and arrive at decisions.
- Moderates the participatory learning process.
- Assists in sharing of information in a participatory way.

The approach is participatory in nature. It develops the farmers' capacity through **facilitation** and **collaboration**, which work best through **group work**, **practical work** and **role play** (folk media).

- **Facilitation.** A trained facilitator helps the learners (farmers or herders) discover the relevance of a topic to their own situation and to learn how to experiment and adapt to change. It uses dialogue, group discussion and exhibits.
- **Collaboration.** This involves working together and works well where everyone has a stake or interest in finding a solution to a selected problem. It requires that everyone is equal, including the facilitator, and demands a high level of trust.
- **Group work.** Group work stimulates independent thinking (and thereby reduced dependency) and activates learners to take part in a two-way discussion and sharing of ideas. The participants learn how to work together in finding solutions. Learners who are shy or unable for cultural reasons to speak out and contribute in a larger setting, often prove to be useful contributors in small groups.
- **Working in the field with farmers.** Practical work in the field (such as testing and comparing methods to restore organic matter to the soil, or building and testing water harvesting structures) is an excellent way of

learning. Fieldwork can be combined with group discussion on a particular subject matter, for example, to compare ways of managing resources, or how to optimize household and community benefits.

- **Role-play.** Role-plays allow the learners – the actors – to share their experiences with other farmer field school members and with non-members. It can include local songs, dances, poems, proverbs, stories, tales, legends and drama. Role-plays help farmer field school members to analyse and understand their mistakes, and perhaps suggest better ways of doing things.

Box 1.3. A good facilitator…

- Is a good listener.
- Is open-minded and respects others' opinions.
- Is cheerful.
- Maintains eye contact.
- Knows the audience in advance.
- Is well prepared and can firmly grasp the subject.
- Dresses appropriately.
- Is well mannered.
- Is composed and confident.
- Is in control of the group.
- Conveys acceptance.
- Manages time well.
- Is impartial.

Core features of farmer field schools

The farmer field school process evolves over time as the farmers become confident and able to identify a problem and find ways to solve it through group discussion, experimentation, analysis of results and decision making. But certain core features do not change. They include:

- Ownership by farmers
- Empowerment of farmers
- Group discovery learning
- Systems approach
- Life education (addresses other livelihood concerns)
- Self-help and self-motivating
- Farmer-centred
- Competent facilitators

Curriculum development:

- Farmer field school members choose topics
- Training based on farmers' knowledge and needs
- Participants are involved in curriculum development

Systematic training process:

- Observation
- Group discussion and analysis
- Conclusion, decision making and action plans for following days or weeks
- Agro-ecosystem analysis
- Regular and frequent meetings

Education principles:

- Skill, not information, is the goal
- Discovery learning
- Learning by doing
- Science-based
- Experiential or problem-based learning
- Experimentation through a study plot
- Non-formal education process

Figure 1.4. Example of a question to stimulate reflection: "What does the group have to do to get credit from a microfinance institutions?

Factors for a successful farmer field school

Besides a skilled facilitator, a successful farmer field school also needs:

- An organized dedicated, committed and willing community.
- A well-defined problem analysis and prioritization.
- Adequate resources and logistical support.
- A clear understanding of the farmer field school concept and procedure by all stakeholders.

- Support and goodwill of the authorities at various levels.
- Appropriate technologies available to test and adapt.
- A consideration of gender issues.

Steps in implementation

Step 1: Training of facilitators

Providers of extension services from both public and private sectors may ask for their staff to be trained as farmer field school facilitators in better land and water, and farming systems management. It is important to select the right candidates. Some factors to consider are:

- The individual's attitude and commitment
- His or her experience and skills in agriculture and in land and water management
- Available institutional support

Box 1.4. Examples of facilitation tools

- Visualization (e.g., through observing the study plot or through questions and reflection)
- Small and large group discussions.
- Informal and structured discussions and analysis.
- Field visits.

Many facilitators and extension staff are not trained in soil and water management, or their knowledge and skills may need refreshing. They may also need to learn how to run a farmer field school. You can train them through a short workshop, or preferably through a series of sessions that focus on practical learning exercises and may last a season or longer.

The enterprise or issue being studied determines the duration of a farmer field school; longer periods may be needed for seeing the benefits of animal breeding, crop rotations or improving soil productivity.

The trainer is responsible for the timetable and ensures there is an ongoing farmer field school to expose the trainee facilitators on hands-on aspects (though learning by doing). The training includes facilitation skills and group dynamics and group-building methods.

The training on the farmer field school approach takes at least 2 weeks to change the facilitators' mindset. This training could be combined with the review with a farming community of problems and opportunities (▶ *3 Review problems and opportunities* below) that leads to the selection of the main

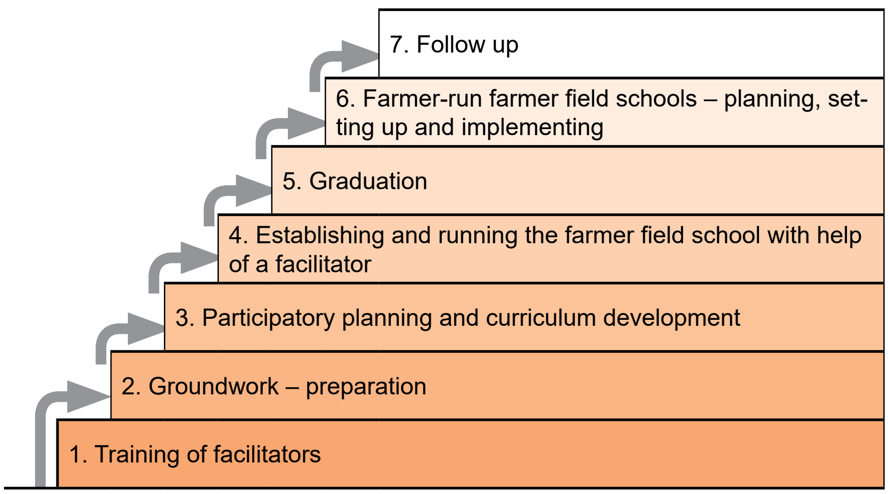


Figure 1.5. Steps in implementing a farmer field school

entry point (► *4 Select an entry point* below). Separate, more in-depth training on the other modules in this book can then follow.

The facilitators also need a sound understanding of improved land and water management – the topics covered in ► *Modules 4–14* of this book. Although an overview can be provided, this is too much to cover in depth in just a 2 weeks' training. So consider breaking it down into shorter training sessions of 2–3 days each on specific topics.

If land and water management specialists are not available to provide continuous support, a longer-term training (e.g., 3 months) is advisable for facilitators. The participants should include both extensionists and farmer leaders: the combination ensures that farmers' needs and realities are addressed as well as building on valuable extension experiences.

Step 2: Groundwork

This step covers the activities in a village or community that prepare for the introduction of the farmer field school concept. This groundwork determines the needs in the area. This diagnosis will be the basis for establishing the farmer field school and developing the curriculum and field trials to address the key problems that have been identified (► *Module 2 Improving land management*). The success of the farmer field school depends on the quality of groundwork. It may include:

Identifying participants. You can work with existing groups of farmers, or with new groups. A group of about 25–30 farmers is manageable and cost effective. In the first few weeks the group may be much larger, but people who joined to obtain free benefits (such as funds and inputs) rather than to learn will soon drop out. The facilitator should encourage men and women of different ages to join, and include some young people.

Identification of study fields. The field to be used as a "classroom" can be hired or donated by one of the farmer field school members or the community. Whatever the arrangement, it is advisable to make some kind of verbal or written agreement to avoid conflicts of interest once an enterprise is in place. The entire group, along with the facilitator, should be involved in carefully choosing the site. Make sure it is representative of the area farmed and can be reached easily.

Step 3: Participatory planning and curriculum development

The facilitator initiates a set of exercises to diagnose the farmers' needs and problems (► *Module 2 Improving land management*). The curriculum is developed based on this diagnosis. The curriculum may include topics such as land and water management, crop husbandry, animal husbandry and horticulture. These are considered together with the farmers' environment, lifestyles, income sources, financial management, labour requirements, risks and uncertainties, and education. The curriculum should:

- Lead towards a better understanding of ecology – the interactions and functions of the ecosystem.
- Enable farmers to make their own decisions.
- Be relevant to local needs and conditions.
- Be experiential and discovery-based.
- Be based on a partnership between the facilitator and farmer field school members.

- Focus on quality of learning and understanding and adaptive management, not just quantity of topics covered.
- Decentralize and spread responsibilities among members.
- Encourage collaboration among different organizations in the area.
- Make use of existing resources.

This step also includes helping the participants develop a vision for the farmer field school, collecting baseline information, and – very important – establishing a plan to monitor the farmer field school's activities (▶ *Module 16 Assessing impacts, learning lessons*).

Step 4: Establishing and running the farmer field school

The farmers enrolled in the farmer field school usually agree when to meet for sessions. The facilitator helps the group draw up a schedule and allocate duties. Here is a typical weekly farmer field school schedule:

- Prayer and roll call
- Field observation (agro-ecosystem analysis)
- Processing of field observations
- Presentation to plenary
- Group dynamics
- Topic of the day (or special topic or exercises)
- Recap of the days' schedule
- Planning for the following week
- Closing prayer

Regular meetings

The type of enterprise to be studied determines how often the farmer field school meets and for how long. For annual crops, the group could meet every 1–2 weeks for one to three seasons of studies. For land and water management, a longer period (two to six seasons) may be needed. The group can use not only the study plot, but also observe the members' farms and the larger community area. Experiments on land and water management are long-term; at the same time the group can do short-term experiments on other topics (such as crop production).

Special topics

Besides the main subject of study the group may be interested in other topics, too. At the start of the farmer field school process, the facilitator can ask members what subjects they might be interested in. He or she can then identify and invite guest speakers to lead discussions on chosen topics such as coping with HIV/AIDS, group cohesion, micro-credit, gender, farmer innovations, and specific opportunities and challenges that farmers face. Such discussions can be scheduled during less-busy times for the farmer field school.

Field days

Field days give non-members from the community, other farmer field schools and interested persons (from district or national levels), a chance to find out what the farmer field school members have learned. The members show the visitors around their study plots and explain the results and other observations. They may use songs and drama to share their experiences.

Agro-ecosystem analysis

Often called **AESA** (pronounced "aa-eh-sa"), this is the cornerstone of the farmer field school approach. It helps farmers to look at interactions within the ecosystem – between plants, soil, water, livestock and the wider environment and the effects of different management practices being studied and compared. Farmers conduct agro-ecosystem analysis by visiting the study plots, observing, taking measurements, recording what they see, and then comparing and analysing the information before deciding what to do. Agro-ecosystem analysis helps farmer field school members identify strengths, weaknesses, opportunities and threats within the ecosystem. By looking at causes of problems such as loss of soil nutrients, erosion, pests or invasive species, the farmers can seek appropriate solutions. The farmer field school members base their farm management decisions on this analysis.

Agro-ecosystem analysis should be conducted at frequent intervals to observe changes. In a crop-based farmer field school it takes place weekly through the growing season so farmers can learn about integrated pest management and practices to improve productivity – timely planting, crop spacing, fertilizer management, and so on. Intervals between observations may be longer; for example, when studying soil erosion and soil moisture management, the timing depends on the rain. Agro-ecosystem analysis helps farmers to monitor impacts of the practices they are testing and to measure their effects on labour, risk, yields and overall farm performance.

► *Module 3 Innovation and experiments* for details on agro-ecosystem analysis.

Exchange visits

The farmer field school members can visit other locations, such as research stations, farmer innovators and agricultural shows. They can also host visits by other farmer field schools on their own plots. Such exchanges are an important part of the farmer field school process as they help motivate farmers to uptake and adapt practices they have seen elsewhere and to cope with changes in their farm context (land pressure, increasing drought incidence, etc.).

Step 5: Graduation

Most farmer field schools use their attendance records to determine who can graduate. The graduation marks the successful participation and completion of the farmer field school cycle or season. It is a festive event where farmers celebrate their achievements and present them to key stakeholders (local government, partners) who are invited with the hope to gain their future support.

Step 6: Farmer-run farmer field schools

After they graduate, selected farmers (those that are very motivated and competent) are supported to start and run farmer-run farmer field schools themselves. These farmers usually receive a short refresher course and follow-up training on facilitation. This ensures sustainability and keeps costs down (important for scaling up farmer field schools at the district or national level). The original facilitator should be working him – or herself out of the current job, by building the farmers' capacity to facilitate their own farmer field schools themselves. When this happens, the facilitator will have new tasks: supervising the new farmer-led schools, and identifying new curricula or farmer groups.

Step 7: Follow up

After the graduation ceremony, most farmer field schools continue as a farmer group. The group may have problems that were not addressed during the farmer field school study cycle, so it is necessary to deal with these. Both technical and socio-economic activities may be needed. Such follow-up work may (or may not) require a facilitator to assist the group, or funds for the study process.

Farmer field school networks

Networks have evolved spontaneously as a way to maintain the collective community action generated by farmer field schools. Well-organized farmer field school networks bring the farmers many benefits. They can:

- Build the capacity of farmer groups in leadership, financial management and conflict resolution.
- Enable the groups to organize the marketing of produce.
- Attract outside institutions to participate in the farmer field school process through contract farming or support for field days or graduations.
- Raise funds and develop proposals for follow-up activities.
- Sustain the learning process after donor-funded projects end.

Linkages to research and extension

The networks and individual farmer field schools must continue to work with innovators, development projects, and extension and research organizations to keep informed of innovations and ideas for new enterprises.

Facilitating farmer field schools on land and water management

The farmer field school approach is a very effective process for participatory learning and technology development in a wide range of farming situations and cultures. Most farmer field schools so far have focused on improving the productivity and managing pests of specific crops. They study a single crop throughout the growing season. The farmer field school also usually includes training on farm business management and new ways to earn money.

Improving the knowledge, understanding and capacities of smallholder farmers on soil and water management is more complex:

- The farmer needs to consider not only one field, but the **whole farm and its environment**. That means, for example, the use of compost or manure to restore nutrients and soil organic matter, and managing water within the catchment.
- The farmer needs to understand land degradation – a set of processes that operate at **larger scales than the farm** – the hillside, the catchment area.
- The farmer's land may be so degraded that improved practices may not produce immediate results in terms of yield (usually the farmer's main

goal). There is a **time lag** – it can take a few years to restore a healthy and productive system.

- Changing management practices may require a major **change of attitude.** The farmer may need support to resist societal pressure, for instance, not to clean the fields, not to plough, or to use weeds and wild plants for soil cover and organic matter. The farmer must appreciate the need to conserve the soil, water and biological resources, to feed the soil as well as his or her livestock, and to diversify crops, land use and habitats to reduce the risks of pests, diseases, drought, storms and floods.

To improve the farmers' understanding and skills on land and water management, the farmer field school approach must be adapted to the specific farming situation, and geared up from a focus on one crop to the farming system as a whole.

Below are some steps to take once local farmers have expressed an interest in land and water management (e.g., through a participatory rural appraisal) and it is decided to start a farmer field school to deal with it.

1 Consult with stakeholders

You should inform local stakeholders about the farmer field school project and get their ideas and suggestions. The stakeholders may include other facilitators or extension staff, technical officers, village and district authorities, staff of other projects in the area, and the private sector (such as fertilizer, seed, agro-chemical and equipment suppliers). Ask them about land and water problems they have come across, farmers' groups that have sought help on this topic, farmer innovators or leaders who are using interesting management practices, and results and experiences from their own interventions. If you coordinate activities with these stakeholders, the wider community and local government, you will not be working on your own. You will be able to draw on their advice and support. Learning from their experiences will also help you avoid mistakes.

2 Select a farmer field school and community

In land and water management it takes time to achieve results. So if you can, start with existing farmer field schools or farmers' groups who are keen to learn more. Begin in locations that are reasonably accessible.

Experience in East Africa has shown that farmers need to go through a crop-based farmer field school (first cycle, ► *Figures 1.6* and *1.7*) first before they move towards more complicated, longer-term land and water management issues (2nd or 3rd cycles).

You may come under pressure from the local authorities to serve certain places for political reasons. So you may need some criteria to help you select where to start. For example:

- Farmers or existing groups have asked for help to address land and water problems.
- You and others can reach the area easily, even during the rainy season.
- The village leaders are motivated and supportive.
- The area has a range of farming situations – differences in climate, terrain, soils, land use, major crops and livestock, pressures on the land.

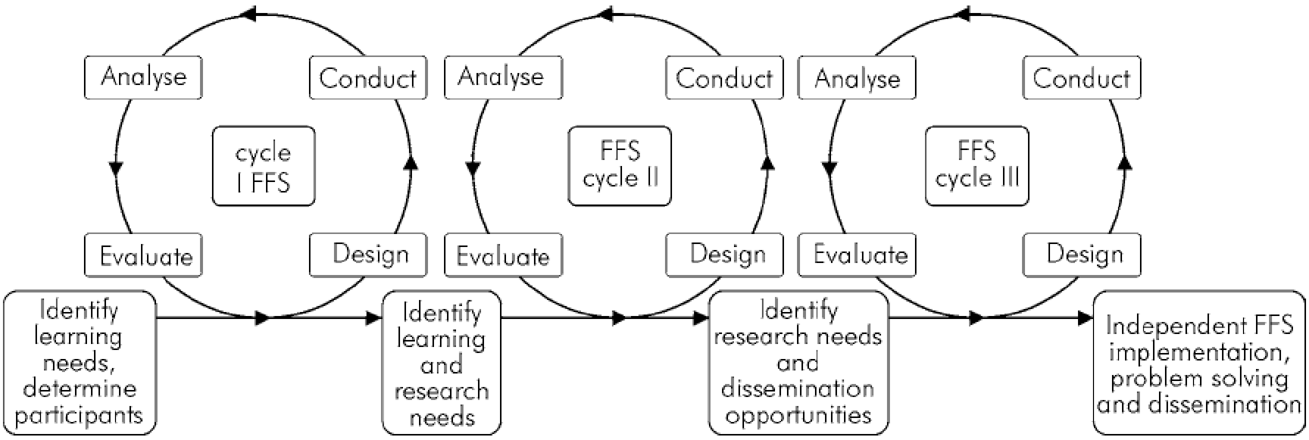
- It will be possible to achieve results. This may be difficult on the most degraded and unproductive lands, the steepest slopes, waterlogged areas, etc. Such areas should be avoided

Once the initial farmer field school has achieved results, you can then target more remote groups and more difficult lands, as new farmer field schools can learn more quickly and easily from the first one.

Support and goodwill of the authorities is an important factor for success. Inform the local leaders and involve them in the setup of the farmer field school, then keep them well informed and engaged in its implementation. They too will learn from the process and will support it.

3 Review problems and opportunities

The next step is to review the land and water resources management situation in the area, analyse the problems that farmers face, and identify opportunities the farmer field school should address. ► *Module 2 Improving land management* takes you through this process.



Adapted from van de Fliert et al., 2001

Figure 1.6. Multiple farmer field school (FFS) cycles

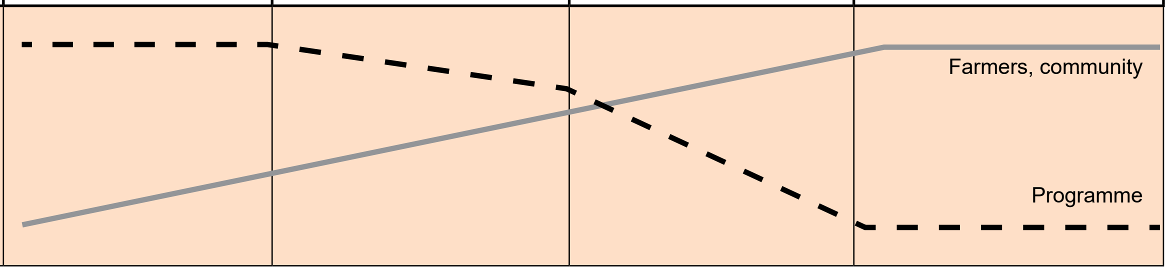
	1st cycle	2nd cycle	3rd cycle	4th cycle (independent)
Emphasis	Learning ecological principles, knowledge, skills, alternative practices through discovery learning Introduction to experimental methodology	More advanced learning Experimentation for adaptive research purposes Farmer-to-farmer dissemination	More advanced learning Experimentation for innovative research Farmer-to-farmer dissemination Collective action	Experimentation for innovative research Farmer-to-farmer dissemination Collective action
Ownership/ role/ support				

Figure 1.7. Shifting emphasis of farmer field schools over four cycles

Classify the local farming systems. You can help the farmer field school group review the different local farming systems and the effects of current soil and water management practices on resource degradation, productivity and livelihoods. Classify the key farming systems and soil and water management practices into groups by:

- **Agro-ecological context**, including the climate, land and water resources, plant and animal species and habitats (vegetation and land use type).
- **Type of farm enterprise,** the farming intensity and use of external inputs. For example, livestock rearing may range from free grazing to stall-fed and intensive keeping; farms may be integrated (including trees, crops, livestock and fish) or specialized, oriented to markets.
- **The socio-economic situation** of the farmers (farm size, education, assets, etc.).

Classifying the farming systems in this way will help identify problems and potential solutions to them. The solutions may include techniques already introduced in the area but which are not widely practised. Or they may build on farmers' innovations, or be new to the area.

Smallholders have limited access to outside inputs, so they have to improve the productivity of their land, water and labour if they are to raise their living standards. That means finding solutions to their main problems:

- Falling yields, poor quality and unreliable harvests due to land degradation.
- Poor infertile soils and unreliable or inadequate rains.
- Increasing pests and diseases, and loss of wild species that provide food, fuel, fibre, timber, etc.
- Increasing workload (time to collect water and fuelwood, hard soils, increasing weed problems) for limited returns (low yields and low market prices).
- Poverty and food insecurity.

Explore linkages among resource management, productivity and livelihoods. If the farmers can improve their land and water management, they can improve the productivity of their land, so sustain and improve their livelihoods. Help the farmers understand these links. ► *Exercise 1.1 Livelihoods analysis.*

Analyse changes in the environment. Farmers have to deal with many stresses and shocks: family illness, drought, flood, pest and disease attacks, volatile prices, conflicts, and so on. Their livelihood is sustainable if they can cope with, and recover from, these problems, without undermining their natural resource base.

You can help the farmers to analyse changes in the environment. ► *Exercise 15.1 Decision making* helps raise their understanding of how a switch from integrated farming (such as a traditional home garden) to specialized cash crop production can affect the environment. When they review the changes they have seen over their lifetimes, they may mention:

- The loss of plants (varieties, species) and animals (breeds, species) that used to provide food and other products, and the loss of habitats (e.g., pastures for dry season grazing, fallow, vegetation that harbours pollinators and beneficial predators, etc).
- The degradation of resources, land shortage, reduced farm productivity.

- Lower soil fertility, less water in the soil and in streams, less wildlife and different insects (► *Exercise 7.3 The bottle game: Nutrient movements*, *Exercise 10.1 The water cycle* and *Module 14 Managing biodiversity*).
- Changes in labour peaks and the time spent on different activities (► *Exercise 2.3 Seasonal calendar*).

These exercises help farmers to identify opportunities to enhance their farming systems, improve their soil organic matter and nutrient management, make better use of water, increase fuelwood supplies, manage pests and diseases, and so on. Without such exercises, farmers tend just to mention what they have seen in other projects, rather than making suggestions based on their own experiences, lost opportunities and other farmers' innovations.

By the end of this diagnostic process, you and the farmers will have identified a number of problems and solutions. It should be clear that a range of actions are needed. ► *Modules 5–14* outline the various technical management strategies to consider. You can use ranking exercises (► *Exercise 2.11 Individual voting* and *Exercise 2.12 Pairwise ranking*) to prioritize the problems and solutions.

4 Select an entry point

Now the challenge is to narrow down the choice from all the issues raised, and to identify the most suitable entry point for the learning process.

Deciding on what subject to start with is very important. Think about it and discuss it carefully with the farmer field school members and other key people. The entry point will influence what learning modules and exercises the farmer field school starts with, what practices to test in the study plot, and the order of the other modules.

Farmers often say "our fields are no longer fertile" or "the rains are no longer as reliable as they used to be". But there are many different reasons for lower yields and increasing effects of drought. They include soil health, plant health, the capacity of plant roots to access nutrients and water, weed competition, and so on. ► *Table 1.1* and *Box 1.5* show some possible situations.

These are starting points only. Don't ignore the other modules – all may be important. Introduce them when appropriate during the farmer field school, according to the farmers' interest, their relevance to the problems addressed, and the time available in the schedule. We explain the learning sequence further below.

5 Train facilitators

If you do not have facilitators who can handle the farmer field school, you will have to train them.

6 Develop the curriculum

Draw up a curriculum through the following steps:

- Hold a workshop with technical resource persons and farmer field school specialists to develop the curriculum, simple study guide materials, practical exercises and sample farmer field school trials (study plots) on the specified topics.
- Prepare a facilitator's guide based on the results of this workshop.
- Assist the facilitators to develop their own materials (for example, if farmers are interested in topics not covered in the guide).

Table 1.1. Possible entry points for farmer field school

Farmers say…	Possible entry point	Also consider these related topics
…Low yields and crop failures are due to inadequate or unreliable rains.	Farm rainwater management (▶ *Module 10*) and harvesting water for crops (▶ *Module 11*)	Help the farmers find what makes the drought worse. For example: • Compacted soils and hardpans may stop water from seeping into the soil and hinder plant growth • Delayed land preparation and late planting mean that early rains may not be used effectively • Poorly adapted crop species – those with a better market value may be more vulnerable to drought. The farmer field school can then learn about soil compaction and its effects and ways to restore and prevent compaction and optimize the use of every drop of rainfall (▶ *Modules 4*, *7* and *8*). It can also explore how to include drought resistant species in the farm and set up producers' groups and find markets for sale of surplus drought resistant species (▶ *Module 15 Farm management, marketing and diversification*).
…The soil is infertile	Soil nutrient management (▶ *Modules 5* and *7*)	Help the farmers learn about soils and poor soil fertility (▶ *Module 4 Knowing* your soil). Discuss the dangers of repetitive tillage and monocultures and find solutions to them in the local system (▶ *Module 8 Conservation agriculture*).
…Livestock are important and could be used better	Livestock management (▶ *Module 9*)	Link this with how to make better use of organic resources (▶ *Module 5 Using organic materials*).

7 Plan the learning sequence

You should plan the farmer field school to cover at least two growing seasons.

- **In the first season**, address the main entry point that the farmers have chosen, as well as essential concepts for field and farm management (nutrient cycling, soil cover, soil organic matter, soil moisture management).
- **In the second season**, you can go on to issues raised in the first season, and to more complex issues such as improved rotations; interactions between soil, water, plants, livestock and wild species; planning and management in the community or catchment, etc.).

This cumulative process should enable farmers to learn enough to apply selected practices in a reasonably integrated way. You can address the specific interests of the members and introduce new topics when appropriate during the year.

Each module in this book has exercises you can include in the learning schedule. For each module, select the most suitable exercises, and draw up a calendar showing when to do them. You can of course, adapt them or develop new exercises as appropriate.

Three of the modules are essential for all farmer field schools:

- ▶ ***Module 3 Innovation and experiments***, helps farmers to build on local innovations and experiences in selecting, designing and monitoring the farmer field school study plot.
- ▶ ***Module 15 Farm management, marketing and diversification***, covers how to make money and reduce risk – a priority for all farmers.

Box 1.5. Example of an entry point

Supposing soil productivity is the main problem, and you select cover crops as your entry point. But land is in short supply. The farmers may not be interested – unless you can show them how the cover crop prevents erosion and increases the productivity of the following crop. How can you do this?

Encourage the farmer field school members to test the cover crops. Get them to plant small plots of several different species, some that produce food or feed, and others that produce a lot of organic matter and protect the soil well. They can then compare the costs and benefits for themselves, and decide which species are best for their own farms.

- ▶ ***Module 16 Assessing impacts, learning lessons***, guides the farmer field school members on how to monitor and evaluate the practices they are testing, as well as their own learning and understanding.

What order should you follow to cover the modules and exercises? That depends in part on the time of year. For example, ▶ *Module 7 Managing plant nutrients* has to be covered at the start of the rains. The modules on understanding the soil (▶ *Module 4*) and livestock management (▶ *Module 9*) can be covered at any time of year. A useful module to introduce towards the end of the farmer field school is on managing diversity (▶ *Module 14*). This helps farmers think about their farming systems as a whole, identify ways to meet their household needs and improve the sustainability and stability of their production.

Box 1.6. Comparing practices

A key issue is to look at benefits of various improved practices compared to current or traditional practices. This requires observing, recording and comparing their effects, for example, on soil moisture, soil cover, soil organic matter, plant health, labour, etc.

A common error of facilitators (especially when they are supported by researchers!) is to compare several good techniques, then to analyse the findings in such a way that farmers believe that one practice is better than the others.

For instance, a facilitator may suggest comparing the use of fertilizers, versus a mulch of grass or *Tithonia* cuttings, versus manure. But in fact **all** these are good practices.

Once their benefits have been proven in season 1, then the key is to learn with the farmer field school how best to combine them in the typical farm in the area, and how to overcome constraints to their wider adoption.

Already in season 1, it is an idea to include a plot where the techniques are combined to show their combined effects.

Remember that a very small-scale farmer may not have the resources to take up the most productive practices. It is important to also encourage farmers to try and adapt the practices for their own farms.

Implementing the farmer field school

Below are some considerations for implementing the field school.

1 Study plot and learning from the environment

A farmer field school typically focuses on a study plot – the experimental field where most of the learning takes place. But improving land and water management means better using resources throughout the farm, as well as from outside. The study plot is still a central feature of farmer field schools that focus on land and water management, as it allows the farmers to experiment, compare and monitor effects of specific practices. But in addition, the members should use their own farms and make wider observations in the area.

Observations. Help the group learn by observing:

- The farmers' practices in managing soils, water, plants and animals, and their effects on agricultural biodiversity and the system at field, farm, community and micro-catchment scales.
- Different farm household types, and their social, economic and environmental assets.
- Farmers' innovations and local knowledge on natural resources management for different farmer types and farming systems.
- Other projects addressing land and water management, agricultural productivity and sustainability in the area.

Study plot. If necessary, help the farmer field school members choose a study plot. This plot should be selected early, before land preparation and planting, otherwise the group will be left with marginal, steep, rocky or swampy land on which to do experiments. ▶ *Module 3 Innovation and experiments* and *Module 16 Assessing impacts, learning lessons* explain how to design and monitor and evaluate the field study. Guide the farmer field school members through agro-ecosystem analysis, as explained in ▶ *Module 3*. This is a key exercise to empower farmers to monitor their studies and to make decisions based on the results. During the start of the farmer field school, discuss the format of the agro-ecosystem analysis and ensure it includes the farmers' own indicators and covers the various soil, water and crop factors. Encourage farmers to look beyond the above-ground part of the plant (the focus in farmer field schools on integrated productivity and pest management) but also to observe plant roots and soil variables.

Farmer plots. Encourage farmer field school members to set aside small areas of their own farms where they can implement the practices they are testing in the study plot. The farmer field school group (or subgroups) should visit the members' farms periodically to check on progress and discuss what they see.

Demonstrations. You may wish to introduce a new technology to farmer field school members. Be careful if you do so: it may not respond directly to the farmers' priorities. You can do this initially through demonstration plots, separate from the study plot. You might also generate interest in the new technology through discussions, videos, case studies or study tours to other farmers who are testing or have started using the technology. Conservation agriculture (► *Module 8*) is an example of a set of techniques or principles that need to be combined and that you might want to introduce in this way.

2 Responsive learning and experience sharing

Use practical exercises to visualize or demonstrate issues, simplify monitoring to the key indicators only relevant to the study, and introduce innovations and observations from the farmers and the area. You can maintain the farmers' interest by continually bringing in new ideas and learning exercises, organizing visits and responding to farmers' questions and concerns through technical advisers and special topics.

Visits by the farmer field school members to other farmer groups, projects, research institutions – even other countries – generate interest and catalyse innovation and sharing of experiences. You may suggest such visits and help plan and organize them.

You can also help the farmer field school develop partnerships and maintain contacts with farmers' associations, decision makers and other stakeholders. Invite them to field days, organize exchange visits, and help the farmer field school network with other groups.

3 Ensuring technical support

As a facilitator, you should not have to work on your own. You and your farmer field school should have close backstopping from technical specialists, farmer innovators, researchers, etc. Be proactive in requesting technical support and following it up as problems arise. This may be a challenge. Agricultural extensionists and technical staff may have good training and experience on crop and livestock husbandry and physical soil conservation measures. But, there is often limited expertise at the district level on integrated soil and water management and agro-ecological practices, which require looking at the farming system as a whole. The farmer field school may be able to use its funds to pay specific technical advisors, and you may be able to arrange for a few members to visit nearby projects or research institutions.

4 Integrated approaches

Although ► *Modules 4–14* address specific land and water management topics, farmers must combine them to improve their management practices and develop an integrated farming system. Think of how you can manage the farmer field school process to help the farmers do this. ► *Box 1.8* gives an example of an integrated system.

Farm visits are a good way to start focusing on the integration of various management techniques. For example, the group might discuss:

- How to make better use of biomass and organic matter on the farm.

Box 1.7. Lessons from Sustainet

- Encourage the farmers to apply at home the tools and practices they learn in the farmer field school.
- Seek support from rural entrepreneurs and the private sector (e.g., for sale of tools and equipment).
- Hold regular field days to disseminate lessons and to stimulate discussion with a wider audience.
- Manage the farmer field school process to develop and adapt the farmers' knowledge and skills. Technicians learn with the farmers, and the farmers share their knowledge.
- Adapt improved practices to different agro-ecosystems through participatory technology development and experiments.
- Empower the farmer field school by registering it with the government, opening a bank account, generating income, and improving members' knowledge and decision making
- Monitor the impacts on the members' households.
- View farming as a business: monitor farm performance, not just yields. Look also at inputs and outputs, labour, health, time saved for other activities, etc.
- Use role plays to reduce jealousy among members and the risk of individuals becoming marginalized.
- Monitor social change – self-esteem, confidence and achievements (e.g. including widows, orphans, women who head households).

The work of Sustainet (the Sustainable Agriculture Information Network) in Africa is coordinated by the African Conservation Tillage Network. www.sustainet.org

- How to improve crop rotations, crop associations (several crops in a field at the same time) and the interactions between crops and livestock.
- How to increase the amount of rain that seeps into the soil, so reducing runoff and erosion
- How to improve the management of water through timely planting, reducing evaporation and water harvesting.
- How to restore degraded soils, for example, through improved rotations, cover crops, improved fallows, agroforestry and controlled grazing.
- How to improve farm diversity and the range and value of products for home use and marketing.

5 Catchment-level considerations

You can help the farmer field school members think of ways to improve land and water management at different levels: the individual field, the farm, the community and micro-catchment. Individual or groups of farmers can do various things that affect the larger catchment: they may harvest water, divert runoff from rocky outcrops and roads, improve the soil cover to increase the amount of water seeping in and recharging groundwater, or reduce runoff and erosion, so improving water quality. If farmers start using such practices, the farmer field school group should monitor their direct effects and their wider impacts.

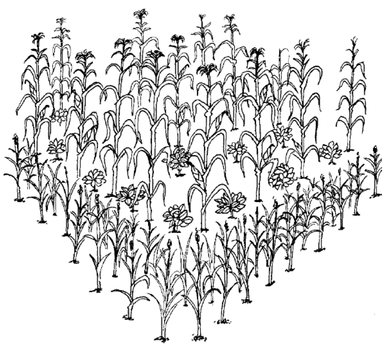


Figure 1.8. Trap crops can be planted in a border around a field.

Start small – at the field and farm level. But as the farmer field school progresses, the members may start considering the wider implications of their practices. Help them realize they might scale up their work to larger areas – the community or micro-catchment level. For example:

Box 1.8. Managing maize pests with "push–pull" plants

ICIPE (the International Centre of Insect Physiology and Ecology) has developed a "push–pull" method to manage pests in maize. Farmers plant two other species together with the maize: one that repels stemborers that attack the maize (the "push"), and another that attracts the stemborers' natural enemies (the "pull"). This way of managing the insects' habitat is based on the age-old African practice of intercropping. It restores the natural balance that modern farming disturbs through its intensive monocultures, misuse of pesticides and soil nutrient depletion.

Napier grass (*Pennisetum purpureum*) and Sudan grass (Sorghum vulgare sudanese) are good at pulling in the stemborers' natural enemies. Plant them as a border around the maize field. These grasses make good fodder for livestock.

Molasses grass (*Melinis minutifolia*) and silverleaf desmodium (*Desmodium uncinatum*) are good crops to repel stemborers. Plant them between the rows of maize. Molasses grass also repels ticks. Desmodium fixes nitrogen, so increases the soil fertility. It also suppresses the parasitic striga weed, and makes excellent forage. Farmers can also earn money by selling desmodium seed.

- Applying conservation agriculture across a micro-catchment can radically reduce erosion and sedimentation, increase the groundwater level and improve the quality of water.
- Harvesting water from roads or rocky outcrops can produce big yield improvements in semi-arid areas.
- Maintaining diversity in the farms and the surrounding area gives beneficial species – earthworms, pollinators and predators that attack crop pests – food and somewhere to live.

6 Linking short-term and long-term benefits

One of your key roles as facilitator is to catalyse the farmers' interest in improving their soil and water management knowledge and skills. You can do this by linking the key problems (▶ *Module 2 Improving land management*) with actions (▶ *Modules 3–14*) and benefits (▶ *Modules 15–16*).

In developing the monitoring system, make sure you clearly link the impacts on the study plot and on individual farms with benefits to the farmers' livelihoods and community – especially income and food security (▶ *Module 16 Assessing impacts, learning lessons*).

A major challenge here is that the soils and agro-ecosystems are often so severely degraded that major efforts are needed to restore them. Farms are often also very small and may be fragmented in small parcels. Farmers need help to find ways to gradually improve their farms. For example, they could concentrate on renovating one part of the farm in the first year, and another part the next year. If they succeed and their productivity rises, they may be interested enough to invest further in improved practices. They may even be willing to take an area out of food production so they can plant cover crops, improved fallow, fodder or pastures, so generating more biomass and improving the soil quality.

You can motivate the farmers by introducing practices that produce quick returns (such as water harvesting or spot-applications of fertilizer) alongside longer-term management strategies such as cover crops.

Figure 1.9. Another integrated approach: instead of planting a pure stand of bananas, farmers in Mbale, Uganda, plant beans and bananas and use mulch.

Box 1.9. Moving to wider community action in Pallisa district, Uganda

Farmer field schools in Sapiri parish, Budaka subcounty, decided on a range of activities to manage their resources:

- **At the farm level,** farmer field school members formed subgroups of 5–6 members each to build soil conservation structures on each others' farms. The subgroups together build the structures on each member's farm in turn.
- **At the village level,** all the farmer field schools agreed to eliminate erosion along the road, to control flooding in their fields, and to plant trees on common land.
- **At the micro-catchment level,** a network of four farmer field schools from four villages has been formed to address concerns that they cannot deal with alone. These concerns include management of swamps, harvesting water from upslope to prevent flooding below, controlling grazing and bush fires, and improving community governance.

7 Specialization and market forces

In most areas, markets, government support and the farmers' need for income have been driving farmers to specialize. The move away from traditional mixed farming often increases farmers' food insecurity and their vulnerability to price fluctuations. In some areas farming communities become dependent on food aid in poor years.

Farmers need encouragement and advice on how to integrate on their farms marketable crops for income with subsistence crops that support food security and maintain the health of farming systems. Solutions include the use of legumes, diversity of crop and livestock enterprises, and adaptation to withstand drought, pest and diseases. How can you help mobilize farmers? For instance to develop networks or associations to exchange seed, market surplus produce or access credit. ► *Module 1 Discovery-based learning* and *Module 15 Farm management, marketing and diversification*.

Many farmers cannot afford fertilizers or improved seed, and local suppliers may sell these inputs only in large packages. This may discourage farmers from testing them. The Farm Input Promotions Strategies programme in Kenya (► *Box 7.3*) is trying to overcome this problem by introducing seeds and fertilizers in small packages. You may be able to organize the members of the farmer field school, or get together with other farmer field schools in a network, to buy such inputs and make small amounts available to individual members to test. Farmers may be reluctant to use fertilizers because of poor response or plant damage, but the farmer field school can show how to obtain good plant response when combined with organic matter and applied correctly (► *Module 7*).

Field days are an opportunity for input suppliers to promote their products. There is a risk that commercial interests hijack the farmer field school. The private sector can provide valuable support, but be careful when partnering with such companies to avoid the farmer learning process being taken over.

8 Effects of poverty and HIV/AIDS

Poverty is widespread in rural Africa. It is made worse by diseases such as malaria and HIV/AIDS, which cut farm productivity and increase food insecurity. HIV/AIDS pushes up health costs, reduces farmers' ability to work and to transfer knowledge, and leaves orphans that need to be taken care of. Families may be forced to sell livestock, and even their food reserves and seed. HIV/AIDS may worsen women's or young people's access to land, credit, water and other resources. Even if the law supports widows and young people, a lot of effort may be needed to make sure they can actually benefit.

HIV/AIDS is an extreme shock that forces families to adjust in many ways (► *Box 1.10*). Households respond differently when one or more of their members fall ill. Better-off families have a stronger safety net, so can cope better than (for example) poor families with a female breadwinner. How families react depends not only on their farming enterprises, but on their other sources of income. Some families may sell assets at rock-bottom prices, pull children out of school, and so on – which tend to push them further into poverty, and force them into risky survival strategies such as sex work.

► *Exercise 1.2 Effects of HIV/AIDS* helps the farmer field school members understand how HIV/AIDS affects rural people, and how improved land and water management can help them cope.

9 Outreach and scaling up

Consider ways to scale up improved land and water management to achieve impacts at the community and catchment levels. Farmers in the farmer field school may have good ideas about what to do. You may be able to find funding to put these into action.

You can widen interest and adoption by other people in the community through field days, visits, awareness raising, involving innovators or champions, and so on.

Many projects have funds for only a limited number of farmer field schools. If this is so, you can try working with other stakeholders to generate support from policymakers, local authorities and donors to expand the farmer field school activities beyond the scope of the project:

- Arrange for policymakers to visit at key times.
- Bring in politicians and the media to generate political interest.
- Write case studies and briefing notes about policy or technical issues and to document the farmer field school's achievements.
- Explore the interest of NGOs and other development partners in scaling up the work.

Farmer field schools can only reach a certain number of farmers. For example, 30 farmer field schools of 20 farmers each would reach 600 farmers in the first year. In the second year, if 4 farmers in each group are trained to become farmer-facilitators and can be supported in setting up new farmer field schools, the effort would reach 2,400 farmers – still a relatively modest number.

How to reach more farmers? Consider using field days and farmer demonstrations, or making videos to show at community centres or marketplaces. Large projects or government agencies are also opportunities to expand your work. Examples are the Kenya Agricultural Productivity Project, the Agricultural Sector Support Programme in Tanzania, and the National Agricultural Advisory Services in Uganda

Another challenge is to sustain momentum and interest, for example, if farmers' priorities change, or if the first year's study plot was not very successful. Make sure you maintain good feedback to the farmer field school, respond to questions, maintain links with research, and facilitate the sharing of experience and expansion of the farmer field school's activities. You may be able to get valuable support and resources if you have good links with district agencies.

Box 1.10. Effects of HIV/AIDS on farming in Zambia

In Zambia, women and young people contribute 70% of the farm labour, but they have little access to productive assets and are marginalized in household and community decision-making.

Households headed by women and young people are most vulnerable to drought and food shortages. This is because:

- They have fewer productive assets (land, ploughs, ox carts, cattle, other livestock)
- They are short of labour, so can cultivate less land cultivated and grow fewer crops
- They get little support from relatives, e.g., to pay school fees or medical expenses.

Traditional laws may mean that women or orphans cannot inherit land or livestock. These people may fall through an already weak social safety net.

Exercise 1.1 Livelihoods analysis

Learning objectives

Identify characteristics of the farmers' lifestyles and differences in livelihoods among local people.

Timing

During sessions in which farmers' land and water management problems and opportunities are identified.

Preparation

–

Duration

1–2 hours.

Materials

Pieces of paper cut in different sizes, marker pens.

This exercise helps the farmers analyse how people in the community earn their living and the organizations that they rely on to support them.

Steps

1. Ask the farmer field school members to say how they earn a living. What are their sources of livelihood? Examples might be growing maize, vegetables or bananas, keeping oxen, renting land out, trading, work for wages. Ask them if they obtain any support from relatives, farming inputs and money sent by a relative in town or abroad. If there is time, they can also describe how other people in the community earn their living as this will help identify other available opportunities.
2. Ask them whether these activities or sources of livelihood are of high, medium or low importance (write the livelihood sources on different paper sizes according to their importance).
3. Draw a circle on the ground to represent the community.
4. Ask the farmers to put the pieces of paper inside the circle (if the livelihood source comes from within the community), outside the circle (if the livelihood comes from outside). For sources that come from both inside and outside, place the paper so it is partly inside and partly outside the circle.
5. Review how far the members are self-reliant or dependent on outside sources.
6. Ask the farmers to identify certain types of households in the village – e.g., better off, medium, poor, landless, female-headed households, minority ethnic group, absent livestock owner, pastoralists, etc. The characteristics of each group can be further studied using ► *Exercise 2.5 Wealth ranking*. This simple exercise will show for each of these household types which livelihood sources they draw on. It provides a good base on which to ask the farmers to suggest ways each of the household types might improve their living standards – by building on local livelihood sources or on outside sources.
7. Ask the farmers from what organizations they receive support (their relative importance and availability can be shown using a Venn diagram ► *Exercise 2.4*). Ask where greater support/better services are needed.

Exercise 1.2 Effects of HIV/AIDS

This exercise helps the farmer field school members understand how HIV/AIDS affects families and their ability to earn a living. The farmer field school can suggest ways these families can change their land and water management so they can cope better. It can also identify ways the community can help these families.

Different families may respond to HIV/AIDS in different ways. For example, a landless family may do things differently from one that has land. The exercise reveals these differences.

You can adapt this exercise to deal with other problems, such as malaria.

Learning objectives

Analyse opportunities and constraints faced by different households affected by HIV/AIDS.

Identify how these households cope with HIV/AIDS.

Timing

During sessions in which farmers' land and water management problems and opportunities are identified.

Preparation

–

Duration

1–2 hours.

Materials

Pieces of paper cut in different sizes, marker pens.

Steps

1. Ask the farmer field school group to think of two or three families that are affected by HIV/AIDS. If possible, choose different types of households: headed by a woman, a man or a child; with or without orphans; with or without their own land.
2. Ask the members to say how the disease affects the family. The effects may be direct (e.g., someone is too ill to work) or indirect (the family has to care for orphans). How does the disease affect what the family has, and what it does? How has it changed the family's farming systems, the crops and animals it raises, its sources of income, whether it hires labour or whether family members go out in search of work? Pay particular attention to the effects on natural resources management. This will help identify opportunities for the farmer field school to improve land and water management.
3. Ask the farmers to imagine how their community might realistically look at some time in the future. How will the families affected by HIV/AIDS be influenced? Can they take part in reaching realistic livelihood goals? Or what support would they need?
4. Ask the farmers to draw a Venn diagram (► *Exercise 2.4*) showing how the government, NGOs, community organizations, the private sector, church and other organizations that work in the community influence the families affected by HIV/AIDS.
5. Ask the farmers to say how the HIV/AIDS-affected households manage to make ends meet. How has it affected their use and management of natural resources? Can these people continue to make ends meet?
6. Identify wider factors that affect the households. What social, cultural, economic and political forces affect them? You may wish to prompt by asking about effects of population growth or migration, infrastructure, markets and access to services, and changes in the natural resource base.
7. Ask the group to suggest ways to help these households. How can they benefit from the farmer field school? Things to think of: times when a lot of labour is needed, times of food shortage, women's access to resources, renting or sharing of land, conflicts over land and forest, opportunities to earn money, crop yield fluctuations.

Questions to stimulate discussion

- How does HIV/AIDS affect families?
- In what way have the families' assets changed over the last five years? You may wish to prompt them to think of different types of assets: hu-

man (e.g., education, health), social (e.g., organizations, social ties), natural (e.g., plants, water, animals), physical (e.g., houses, land) and financial (e.g., savings).

- How has this affected them (e.g., nutrition, access to food, income, health, vulnerability, use of natural resources)?
- Which households are most at risk to losing out because of HIV/AIDS?
- What are the main causes for declining assets if a family member is ill or has died?
- What other things (other than HIV/AIDS) can affect the family's health and living standards?
- What organizations affect these families? In what way, good and bad? How do families cope with the disease?
- What do they do to make ends meet?
- What kinds of help do they get (e.g., from the extended family, other families, the community, NGOs, government)?
- Have families broken up? (e.g., do they send out children to foster parents, or do children get married early?)
- How else do families try to support themselves (e.g., poaching, collecting wild foods, sex work)?
- What would these families like to do to earn a living?

Module 2. Improving land management

This module explains how to prepare for farmer field school activities on land and water issues. The module has two main sections. The first explains how to analyse the farming area. This is important to understand how land use and farm management practices affect resources and livelihoods, both now and in the past. The second section explains how to identify farming problems, analyse their cause, identify potential solutions, and select the most interesting options for studying or testing in the farmer field school.

Learning objectives

After studying this module, you should be able to:

Describe the farming environment and identify problems and needs in resource management and farm productivity.

Analyse these problems and identify possible ways to solve them, with particular attention to land, water, plant and livestock interactions.

Prioritize the potential solutions.

Select best options for the farmer field school to study and adapt.

How to use this module?

This module presents a series of steps you and the farmer field school can follow to analyse their situation and come up with solutions to their problems. Each step has several exercises to choose from (► *Table 2.1*). If you have done **participatory rural appraisal** (often called **PRA**), you may already be familiar with many of these exercises. At the end of this process, the farmers will be able to start testing new practices or potential solutions to specific land and water management problems.

This module covers the following steps:

1. Understanding the current farming situation and natural resources
2. Studying the social and economic situation
3. Identifying problems and their causes
4. Identifying possible solutions to the problems

The next module, ► *Module 3 Innovation and experiments*, covers the next steps:

5. Building on local knowledge and innovations
6. Experimenting with promising solutions
7. Monitoring the results of these experiments.

What is the situation?

All farming communities encounter problems they cannot solve directly. Before looking for solutions, the farmer field school should analyse the farming area so the members understand the problems and what causes them.

Some of this analysis is done before the farmer field school itself is launched. As part of the preparatory work paving the way for the farmer field school, your organization may lead the community through a series of exercises known as **participatory rural appraisal**. These exercises are done with people from the whole community, including potential members of the farmer field school. The organization will also meet local leaders, conduct interviews and hold community meetings. All these preparatory activities are called **groundwork**.

Once the farmer field school is formed, it may be necessary to review the exercises in more depth, or even repeat some of them focusing on land and water management issues.

Table 2.1. Exercises to analyse problems and select solutions for testing

Step	Exercises*
1 What is the situation?	**Natural resources and the farming situation** • Resource mapping (▶ *Exercise 2.1*) • Transect walk (▶ *Exercise 2.2*) • Observation of soil characteristics (▶ *Module 4 Knowing your soil*) • Seasonal calendar (▶ *Exercise 2.3*) **Organizations** • Venn diagrams (▶ *Exercise 2.4*) **Social and economic conditions** • Gather baseline data (▶ *Module 16 Assessing impacts, learning lessons*) • Wealth ranking (▶ *Exercise 2.5*) • Gender and socio-economic analysis (▶ *Exercise 2.6*)
2 What are the problems? What causes them?	• Identifying farming problems and constraints (▶ *Exercise 2.7*) • Identifying problems at different times of year (▶ *Exercise 2.8*) • Problem tree or causal diagram (▶ *Exercise 2.9*) • Problem analysis chart (▶ *Exercise 2.10*)
3 How to solve the problems?	• Individual voting (▶ *Exercise 2.11*) • Pairwise ranking (▶ *Exercise 2.12*) • Identifying possible solutions for testing (▶ *Exercise 2.13*) • Identifying local innovations (▶ *Exercise 3.1*)

* Some of the exercises to be done at this stage are covered in later modules.

Analysing the farming environment and land and water management issues takes time and effort. The farmers need to consider their use of resources on and off farm, across the community, and at different time scales (seasons, rotations over several years, etc.). This means that starting a farmer field school on land and water management is more intensive and will take longer than, for example, starting one on integrated pest management, which can focus on one crop and one growing season.

The initial diagnosis covers the following issues:

- Natural resources and farming
- Organizations that work in the community, or that affect it
- The social and economic situation.

Natural resources and farming

It is important to build on what the farmers know, the farming practices they already use, and the natural surroundings of the farming area. Here are some ways to do this.

Direct observation

Observation is the most-common way for farmer field school members to make field assessments. Encourage the farmers to use their eyes, discuss what they see, and identify visual indicators for things they cannot see directly – such as the soil properties below the ground, plant nutrient deficiencies, animal health, and so on.

When the farmer field school members assess their farming environment, they can make notes on the various land use types, landforms and slopes, soils, water resources, vegetation, livestock, pests and diseases, and the extent and severity of degradation. They can relate what they see to what they do – land use, cropping, livestock keeping, cultivation practices, and so on. What they see depends on the time of year: for example, some areas may be waterlogged in the rainy season. Sedges growing in the field betray such spots during drier periods. Striga (a parasitic weed) and *Imperata* grass in fields are signs of poor fertility.

Mapping resources

Maps are a very useful way to describe the farming environment. A small group of farmer field school members draws a map of the village and its surrounding area: the major features such as hills and valleys, rivers and forests, roads and houses. This base map can be used to illustrate many different more specific biophysical and socio-economic features. Different groups might be asked to map different features.

Maps can be used in many different ways:

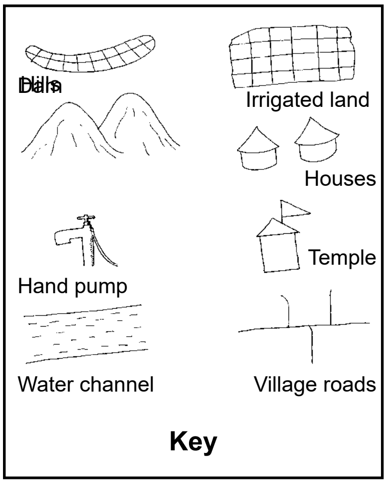
- Preparing maps during the first farmer field school sessions helps members diagnose problems and opportunities.
- They help the farmer field school members agree on how they perceive the local farming situation, the biophysical resources and socio-economic situation in the community.
- They help members think about differences in land use, soil type, water availability, and risks such as drought, erosion, waterlogging and flooding.
- They can stimulate discussion about land use changes or resource degradation (soil fertility, erosion, deforestation, pollution, etc.) due to rising human and livestock numbers or management practices.
- They can be a basis for discussions on the resources used by different households – and by men, women, young and old in the same household (► *Exercise 2.6 Gender and socio-economic analysis*).
- They can reveal how decisions are made locally, and how regulations and bylaws governing the use of resources are applied.
- They can be used to monitor changes over time and the impacts of the farmer field school's work.

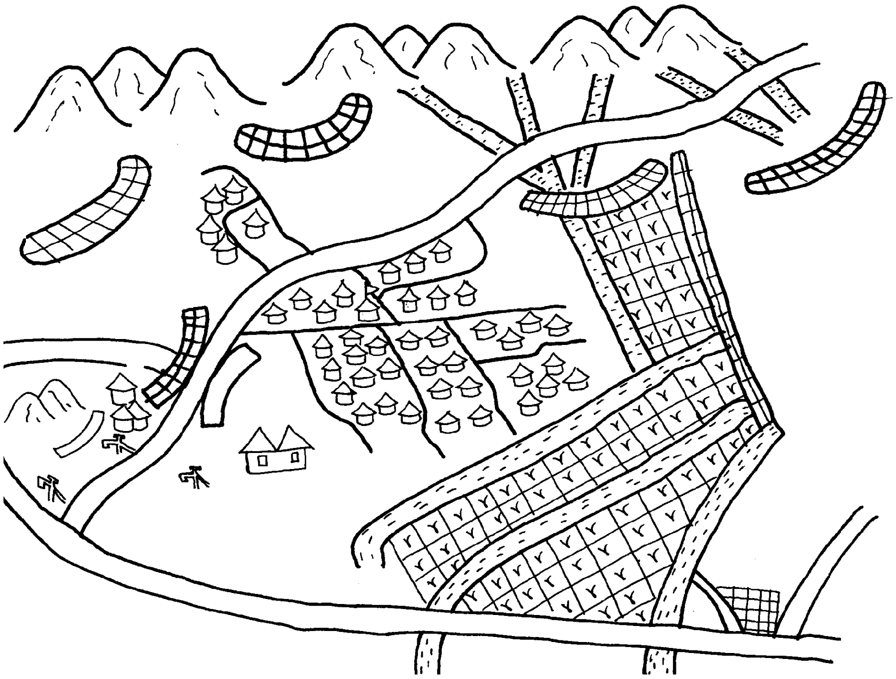
Instead of maps, the farmer field school may want to make models from papier maché.

Several types of maps can be made.

- **A general resource map of the community and its territory**. This can show different land types, farmer field school members' fields, communal pastures, woodlands, catchment boundaries, etc. (► *Figure 2.1*). The area covered will depend on the type of activity. For example, grazing normally covers a much wider area than cropping.

Figure 2.1. A general resource map of a community





- **A single-topic map**, drawn by a local expert, can show specific features: a soil map can show soil types and suitability for various uses, it can use local names for the soils; a groundwater map can show the location and depths of wells and boreholes and location of springs; a land tenure map can distinguish where land is owned, rented or under communal management as well as farm size.
- **Maps of specific problems** can show the location, severity and extent of pest attacks, soil erosion, salinity and other problems. They can also be used to identify land uses and management practices where such problems do not occur – so revealing ways to improve management and productivity.
- **Time-series maps**. A series of maps can show changes over time. For example, one map may describe the situation 30 or 50 years ago; another may show the present situation; and a third might show how the farmers expect (or would like) the area to look in 10 or 20 years' time. Such a set of maps can form the basis for lively discussions on the reasons for the changes, and what can be done to improve natural resources management.
- **Catchment maps:** A broader catchment map, showing a bigger area than just the community itself, can show environmental problems that require catchment-scale solutions (►*Figure 2.2*). Such problems might include runoff from land upslope causing erosion downslope, pollution, deforestation or overgrazing. The map can show the causes, areas affected and where interventions are needed: soil conservation measures, cutoff drains, reservoirs, reforestation, watering points, cattle corridors and so on. A catchment map can also help plan the allocation of water for household use, irrigation and other uses. It can show how land use upstream may affect areas downstream, and highlight the need for communities to work together to solve problems.

Maps can be revised later as the farmer field school progresses and as new information emerges.

► *Exercise 2.1 Resource mapping.*

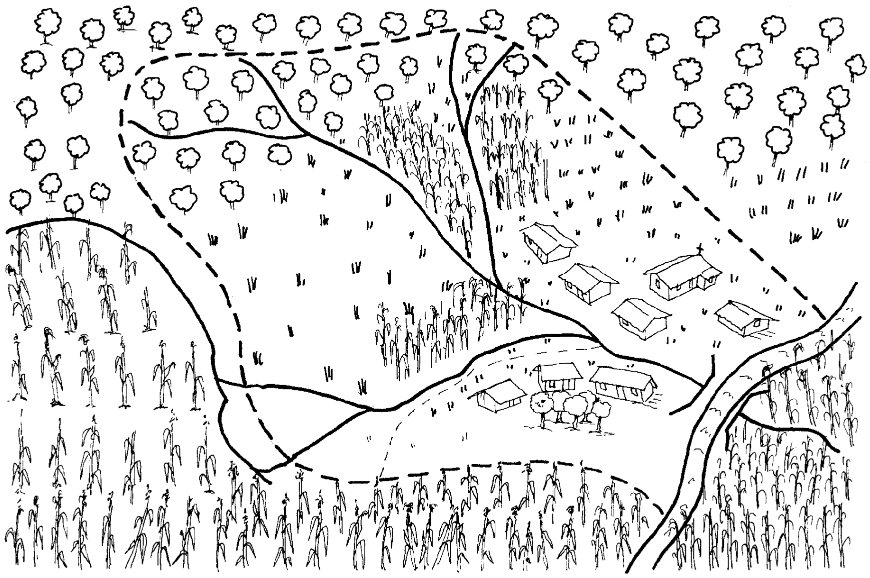


Figure 2.2. A catchment map

Walking through the community

Some or all of the farmer field school members, other locals (informants), and perhaps some technical specialists, go on a "transect walk" together around the community (► *Exercise 2.2*). Choose the route to cover the range of land types in the community. It should cross different landforms, land uses, farm types and areas with resource management problems. The resource map (► *Exercise 2.1*) may be helpful in choosing the best route.

A transect walk helps farmers think about the linkages between the type of terrain, the soil quality, water and biological resources, as well as differences in the way farmers manage these resources. The farmers can look at how the vegetation affects runoff and erosion, and how management practices influence soil cover, soil moisture, soil organic matter and life – signs of earthworms, beetles and other organisms in the soil. A walk is a good way to start finding out what farmers know about the land quality and effects of their management practices. Don't rely only on the walk to do this, though: back it up with other exercises with other farmers.

Prepare a transect diagram of the route ► *Exercise 2.2.* Mark the walk and the major findings on the resource map. After the walk, check that the information is correct and discuss the findings with all the farmer field school members (and perhaps other local people too).

► *Exercise 4.1 Soil walk*

Looking at the soil

Ask the participants to think about what crops, trees and pastures need from the soil. You can compare plants to people: both need to eat (plants absorb nutrients), drink (plants take in water), to breathe (plants take in oxygen through their roots and leaves), room to grow (plants need soils that are loose enough for shoots and roots to develop), a stable environment (plants need to grow in places that are free of erosion, landslides and flooding), and a healthy environment (organisms from earthworms to microbes keep the soil healthy).

► *Module 4 Knowing your soil*

Figure 2.3. Transect walk

Finding out what happens when

You can use a seasonal calendar (▶ *Exercise 2.3* and *Exercise 2.8 Identifying problems at different times of year*) to record key happenings throughout the year: the rainy and dry seasons, planting and harvesting, pest and disease attacks, unusually intense storms and flooding or drought, introduction of a new crop, and so on. Use the calendar to note what men and women and the youth in the community do and who decides (they probably have different activities and decision making responsibilities), and how long it takes them.

The calendar helps identify periods when there are labour shortages, or when people have little to do. It can show when resources are plentiful or are scarce and if and when the locals rely on wild foods or external food aid. It can show which person in the family does what, so highlights gender biases.

You can use the calendar as a basis for a discussion on ways to improve productivity (e.g., by timely planting, rotations, mixed farming, planting extra crops during the slack period), reduce workload (e.g., through conservation agriculture practices to minimize tillage and weeding), or reducing pressure on resources (e.g., by planting trees for fuel and building poles).

Organizations in the community

If a farmer manages his or her land poorly or well, this affects the neighbours' land. Poor crop management encourages pests, diseases and weeds. Animals that graze uncontrolled can damage crops and cause erosion. Lack of soil cover increases runoff and may cause erosion and flooding further down the slope.

For improved land and water management to be successful, neighbouring farmers should work together to address common problems and improve their management practices over a large area. Village organizations and service providers can help them do this.

That is why it is important to identify the key organizations in the community, as well as outside organizations that influence agricultural and rural development. The facilitator should help the farmers to assess how these organizations might support (or hinder) the farmer field school activities, overcome obstacles and support wider uptake of better land management practices.

It is sometimes easier to start actions on individual farms, and with a small number of people in a few farmer field schools. But even at this stage, think of linking with other organizations with a view to scaling up to more groups and across wider areas in the following years.

► *Exercise 2.4 Venn diagram*

The social and economic situation

Farmers need to be able and motivated to experiment and adopt better land management practices. This requires the analysis of social and economic conditions in the area: to find out about access to resources and equipment, education levels, health and ability to work, and the needs and priorities of different types of households.

You can work with the farmer field school to do this in various ways. Some tools are covered in ► *Module 15 Farm management, marketing and diversification*. Two are included in this module: wealth ranking and gender and socio-economic analysis.

Wealth ranking (► *Exercise 2.5*) divides the community into three or more groups: well-off, average, and less well-off. You need to know this to make sure that interventions are adapted to benefit each target group as appropriate. It would be disappointing if the farmer field school included only the better-off people in the community (for example), or if only a small group of people were to benefit from improved land and water management.

It is difficult to reach the poorest people in the community. They usually do not have time to attend a farmer field school – they may have to look after sick relatives, or may have to work every day to earn money. However, encourage the farmer field school to find ways to help such people benefit from its activities and what it learns.

Gender and socio-economic analysis (► *Exercise 2.6*) looks at the differences between men and women in the community – their roles and responsibilities, access and use of resources, interests and potentials. But it does not just look at men and women. It also looks at the needs and potentials of different groups in the community (rich/poor, young/old, households headed by women, orphans, etc.).

Make sure that you use these exercises in a sensitive way. People can easily misunderstand your intentions, get upset or feel threatened if they are used in the wrong way.

These exercises compile information on many aspects of the community:

- Farm and household resources, including labour and capital
- Access to land, water and biological resources
- Local knowledge and skills
- Access to inputs and support services
- Problems and opportunities in improving resource management and productivity
- The specific needs and interests of individual households and the wider community.

What are the problems? What causes them?

The previous exercises have focused on understanding the current situation. During these exercises, you should encourage the farmer field school members to identify and discuss the problems they face. It's now time to focus on the problems in more depth. What are they? When do they occur? What causes them? This phase includes four exercises to look at these questions.

Identifying farming problems and constraints (▶ *Exercise 2.7*) brings together all the problems mentioned in the previous exercises, and to group them into categories. It shows how problems are related to each other, and reveals whether different people think different problems are important. This can help them decide which ones they should tackle first.

Identifying problems at different times of year (▶ *Exercise 2.8*) focuses on problems that occur at different seasons: flooding during the rainy season, for example. But it may be necessary to find a solution at another time of year (the dry season may be the best time to build structures to control flooding). This exercise draws on the seasonal calendar that the farmer field school prepared earlier (▶ *Exercise 2.3*).

Problem tree or **causal diagram** (▶ *Exercise 2.9*). This exercise looks for the causes and effects of the individual problems listed in the previous two exercises. It helps the farmers think through the causes of the problems they identify, so they can decide which of the root causes they should tackle.

Problem analysis chart (▶ *Exercise 2.10*). The final exercise in this series focuses on what people already do to overcome the problems they face, as well as explores what else they might be able to do. It leads into the next stage in the process – agreeing on which problems are the most important to be tackled by the farmer field school and looking for appropriate solutions.

How to solve the problems?

Once the participants have identified the problems, they can analyse what they can do about them. This will help identify the most important problems for which there are feasible solutions and then identify possible solutions they would like to test in the farmer field school. Previous exercises will have touched on these subjects; build on those discussions where possible.

It is not possible in a farmer field school to study all the problems, or all the possible ways to solve any one problem. The farmer field school members need to choose one or two problems, and one or two possible solutions for each. It makes sense to study the most important problem first, and for everyone to agree on what this is and what solutions might be tried.

Problem prioritization can be done in many ways. If there are a lot of problems to be ranked, you can use individual voting (▶ *Exercise 2.11*). If there are just a few problems (no more than five), you can use pairwise ranking (▶ *Exercise 2.12*).

Identifying possible solutions to the problems. To help the group find solutions to the priority problems identified by the group it is a good idea to bring in outside technical specialists who can provide information and advice. Make sure that they do not dominate the session, though, as this will take the all-important initiative away from the farmers.

Potential solutions can come from any source: the farmers' own knowledge and experience, things they have seen or heard of elsewhere, or from the outside specialists (▶ *Exercise 2.13 Identifying possible solutions for testing*).

Exercise 2.1 Resource mapping

Resource mapping helps us to learn about a community and its resource base. It is possible to draw maps of the village, an irrigation scheme, a catchment area, a swamp, and so on. Accuracy is not the primary concern; it is more important to gather information about how people perceive their resources. Maps may include:

- Landscape and land type (hills, valleys, flat areas, slopes, soil type, rocky or sandy areas, swamps, etc.) as well as differences in altitude, rainfall and temperature which influence farm enterprises.
- Water resources (lakes, rivers, streams, springs, waterlogging, wetlands, salinity), other water points and water use (wells, boreholes, springs, reservoirs, irrigation canals, rock outcrops that may be useful for water harvesting),
- Infrastructure (roads, bridges, houses, churches, schools, market places, other buildings)
- Land use (cropped areas, crop types, wet and dry season grazing areas, forest) and land tenure issues (private or common land, owner or tenant or leasehold farmer, farm size and fragmentation)
- Problem areas (erosion, pollution, deforestation, invasive species such as *Striga* or *Prosopis*, etc.)

You can use maps as a planning too, for example where to put structures to harvest and store water.

Steps

1. Ask a participant to place a rock or leaf on the ground to represent an important landmark in the community.
2. Ask the other participants to mark other important things on the map: roads, houses, major buildings, rivers, and so on. The map can even be drawn on the ground with sticks and using stones or other materials to locate certain features. Don't interrupt unless they stop in which case prompt them on what else of importance they could add.
3. Ask the participants to show the land types on the map: cropping, grazing, wetland, rock outcrops, and so on. Ask them also to mark their own farms on the map.
4. When the map is finished, ask the participants to describe it and to discuss what it shows. Ask about anything that is unclear. Make sure they have marked things like the north point, directions to nearby places, and so on.
5. You can then use this basic resource map for discussing other information on land degradation, solutions that people have found or innovations they have tried out.
6. Finally, you might want to ask them to draw another map of how they would like to see the future. This allows for some preliminary planning, and encourages people to contribute their ideas.
7. Leave the maps with the community. Take a photograph or, if necessary, copy the map onto paper and keep it for reference.

Learning objectives

Identify and locate the different land use and soil types in the community and discuss the effects of management on the farm and in the surrounding area.

Produce maps showing key features of the area, and discuss how they relate to each other.

Timing

Early in the farmer field school, when land and water management problems and opportunities are being identified.

Preparation

Choose somewhere suitable to draw the map, such as a large, clear, sandy space.

Duration

2 hours.

Materials

Sticks, pebbles, leaves, sawdust, flour, other local materials; large sheets of paper, marker pens.

Adapted from

Jordans (1998)

Questions to stimulate discussion

Figure 2.4. Resource mapping

- What resources are in ample supply? Which ones are scarce?
- What resources are used or unused? Which are degrading? Which are improving?
- Who decides who can use the land? The water? Other important resources?
- Who owns the land? How about land tenure security?
- Do men and women have different rights to use land and water? How about people from different ethnic groups? Rich and poor?
- How do people manage the land and water and biological resources? What management practices do they use on their farms and in the surrounding area (such as burning or cattle grazing)?

Notes

Instead of using the ground, the participants can draw use marker pens to draw a map on a big sheet of paper. Or they can redraw it on paper once it is finished on the ground. Post the paper on the wall as a permanent record.

Sometimes women are reluctant to contribute to the map. If so, ask them to draw a separate map. They often show different things from the men – things they see as important.

If the community has already drawn a map through a participatory appraisal exercise, ask the farmers to review and update it. Ask about things the old map does not show. It may be better to get them to draw a new map rather than just adding features to the old one.

You can ask participants to draw maps showing specific things: crop types and yields, disease problems, who in the family does what, soil types, and so on. You can then use the map as a basis for discussing these issues.

Participants can also draw maps of their own farms and use these for analysing problems and planning improvements.

Maps are very useful for monitoring and evaluation as they can show changes over time. If participants draw a map at the end of the farmer field school cycle, they can compare it with the map at the start of the farmer field school to see what changes have taken place.

Exercise 2.2 Transect walk

The transect walk is a way to gather information on the relationships between the landscape, land use, farming systems, soils, water and crop problems. It stimulates discussion of local problems, possible solutions and potential opportunities.

Learning objectives

Become familiar with the landscape in and around the community.

Understand the relationships between the landscape, land use, farming systems, and soil, water and crop problems.

Timing

Early in the farmer field school, when land and water management problems and opportunities are being identified.

Preparation

Choose a route across the community area that goes through as many different landforms and land use types as possible – e.g., from the ridge down into the valley. (This is because the land and water conditions depend heavily on the landforms.)

Duration

Several hours, depending on the length of the route.

Materials

Notepaper, pencils, large sheet of paper, marker pens (or blackboard and chalk).

Adapted from

FAO (2000)

Steps

1. Explain to the group that before they think about how they might change their farming practices, it is important to look at what they do now, the problems they face, and solutions that have already been tested.
2. Explain the objective of the transect walk, and with the participants choose the best route to follow. They may propose two shorter transects rather than one long one, to include the various land types. Show them how to note down the information using a transect sketch.
3. During the walk, stop frequently at interesting places, and make sure you capture the differences in land use and soil type. The participants should observe the main features of the farming environment, discuss the differences, and record what they see at each place. The participants, and people living nearby, should discuss and record these seven aspects:

- **Soil type**. Use the farmers' names for the soils. If these are very simplistic (e.g., they just refer to the colour), ask about details such as stoniness, depth, fertility or management needs.
- **Crops and vegetation.** Use local terms and criteria to describe the cropping systems, pasture types, trees and other vegetation.
- **Animals**. Record the type and approximate numbers of livestock, and whether they are stall-fed, ranched or free grazing and whether the herds belong to locals or outsiders.
- **Water**. Note where the transect crosses or is near to rivers, streams, springs and reservoirs. Ask whether they always have water in them, or how long they are dry, and about flooding: how often does it occur, and where?
- **Problems**. Ask about any problems related to soils, plant nutrients, crops and water, livestock, pests and diseases. Ask what changes the participants have seen in recent years, such as erosion, burning, need for fertilizer, crops, yields, pollution. Ask them to point out things (such as certain types of plants) that indicate the changes. If you do not know the botanical name of the plant, take a sample and note down its local name.
- **Management practices**. For pasture and forest land, describe management practices such as fencing, controlled burning, seeding, selective felling and coppicing. For cropland, describe the soil management practices (tillage, soil conservation measures, fallows), cropping practices (rotations, intercropping, burning, weeding), nutrient practices (manuring, compost, fertilization, grazing of residues), water management practices (mulching, water harvesting, irrigation, drainage). Note what can be seen during the walk, but also ask what happens at other times of year.
- **Opportunities**. Note what people say about ways to improve the management of resources, increase productivity and reduce land degradation.

4. At the end of the walk, ask one of the participants to draw a profile (cross-section) of the route on the big sheet of paper (or on the blackboard). Mark the most important land types and features (hilltops, river, village,

forest, crops, etc.) on this profile. Use little drawings to show trees, houses, crops, and so on.

5. Divide the participants into seven smaller groups. Ask each group to discuss one of the seven aspects. Ask them to write on the diagram a brief summary of the most important information they noted at each stop.
6. Start a general discussion of the information on the diagram. Add any further details to the diagram. Keep the finished diagram in the farmer field school for future use.

Questions to stimulate discussion

- Are there differences in the soil from one place to another?
- How does the soil type affect the land use and management practices?

Notes

The route does not have to be in a straight line, and you don't have to go along the road! That might give a false impression of the area. You might start at the top of the hill and walk down into the valley to the river. Try to cross as many land uses and soil types as possible. Walk at right angles to a river or canal rather than in the same direction as it.

It may not be practical for everyone in the farmer field school to go on the walk. Instead, the farmer field school can select a few members to do this exercise. Make sure they include both men and women. Or perhaps the farmer field school could divide into two or three smaller groups, each to go along separate routes (you will need a facilitator to go with each group). Meet with all the farmer field school members immediately after each walk to discuss and review the findings.

Different people can be responsible for recording different aspects of what they see. If most of the farmers are illiterate, you may have to take the notes yourself. Make sure you record information provided by the participants.

Try to avoid biases in the information collected. For example, don't just talk to better-off and more vocal male farmers. Make sure that poorer farmers, female farmers and single women also have their say, as they may have different knowledge and perceptions.

Figure 2.5. Discussing aspects of the transect walk

Exercise 2.3 Seasonal calendar

Seasonal calendars help farmers explore the changes on the farm that take place over the year. They can be used to study many things: the times of planting and harvesting, the availability of food and water, the incidence of pests and diseases, the rise and fall of prices, how much work people have at different times of year, and how their incomes change. They can also look at historical changes over several years, the frequency and dates of serious drought or storms, the introduction of new crops or farm enterprises, available support services, legislation, etc. The example below is about seasonal changes.

Learning objectives

Visualize farming activities on an annual calendar.

Understand the changes in farming and in the environment that occur during the year.

Timing

Early in the farmer field school, when land and water management problems and opportunities are being identified.

Preparation

Choose somewhere suitable to draw the map, such as a large, clear, sandy space.

Duration

1 hour.

Materials

Sticks, pebbles, leaves or other local materials; area of flat bare ground or large sheet of paper, marker pens.

Adapted from

Jordans (1998)

Steps

1. Draw a line across the top of the piece of ground (or the paper). Explain that the line represents a year. Ask how people divide up the year – into months, seasons, etc. Ask the participants to mark these divisions along the line.
2. It is usually easiest to start by asking about rainfall. Ask the participants to put pebbles under each month (or other division) of the calendar to show how much rain falls then (more pebbles mean more rain). At the start of the row of pebbles, write a letter R (for "rain") or draw a water drop to show this row stands for rain.
3. Draw another horizontal line under the row of stones, and the participants to make another calendar showing how much work the men put into farming (more stones mean more work is needed). Put a letter "M" at the start of the row (for "men's labour"), or draw a little picture of a man working.
4. Do the same for the amount of work women put into farming. Mark this with the letter "W" (or a picture of a woman).
5. Repeat this process, one calendar under another, for other topics: food availability, water availability, income sources, expenditures, and so on, until all the seasonal issues are covered. In each case, draw a symbol or letter next to each calendar to show what it represents. Ask the participants to explain how they manage in times of food or water shortage, and to say at what time of year they have major expenses, where they obtain the income, and so on.

Questions to stimulate discussion

- How do women's calendars compare with men's? What are the busiest periods for women and for men? Are there daily, seasonal or yearly labour peaks and shortages?
- How does food availability vary over the year? Are there periods of hunger?
- How does water availability vary over the year for various uses (household, small and large livestock, irrigation)? Are there periods of disease? What diseases occur when?
- How does income vary over the year? Are there periods of no income?
- What are the key linkages among the different calendars (e.g., water availability and food supply, rainfall and labour, or food availability and disease occurrence)?

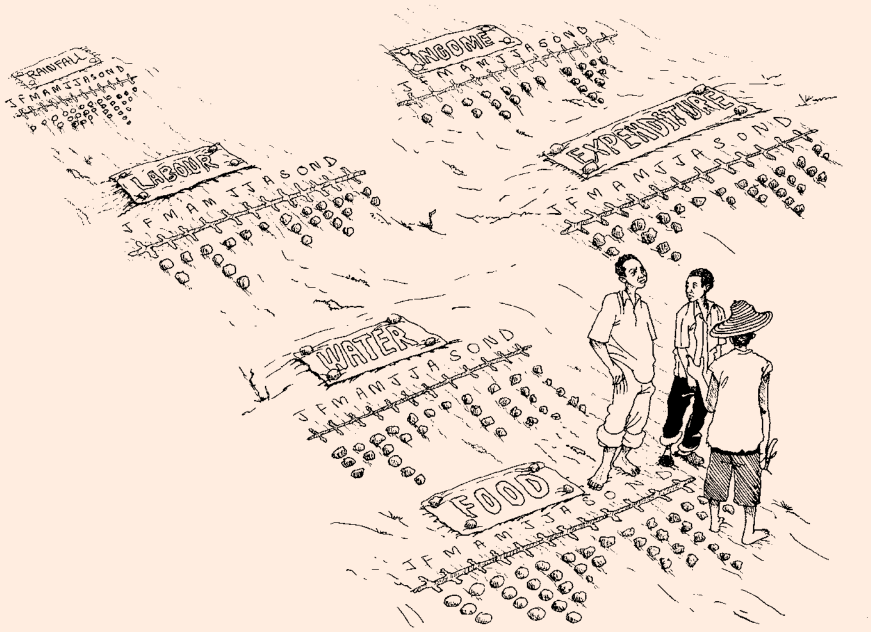


Figure 2.6. One way of showing a seasonal calendar

Notes

Instead of using the ground, the participants can use marker pens to draw a calendar on a big sheet of paper. Or they can redraw it on paper once it is finished on the ground. The farmer field school should keep the calendar as a permanent record. If possible, post the paper on the wall in a place where it can be referred to in further discussions.

Make sure the calendars for the various topics are aligned with the rainfall calendar (i.e. January, February, etc. are at the same place on each calendar). That makes it easy to see relationships, such as that between disease and water availability.

Exercise 2.4 Venn diagram

A Venn diagram shows the institutions in the community, and outside organizations that affect it, and the relationships among them. Venn diagrams use round pieces of paper which look a bit like chapattis – so they are sometimes called "chapatti diagrams".

Steps

1. Explain the objective of the exercise, then divide people into groups of men and women (they usually have different perceptions about the importance of organizations).
2. Ask each group to draw a big circle on the floor. This represents the community.
3. Ask them to list the different institutions in the community, or outside organizations that affect it.
4. Ask about the different roles of the organizations. Ask which ones are more important. Get one participant in each group to write the names of each organization on the ovals of paper – one name on each sheet. A big oval means an organization that is important for the village; a small oval means that it is less important.
5. Ask the participants to put the ovals inside the big circle (if the organization is part of the community), outside it (if it is external to the community), or overlapping with it (if it is part inside and part outside).
6. The participants should position the ovals so that organizations that work together are close together or overlap with each other. A big overlap means close cooperation. Organizations that have little to do with each other should be put far apart.
7. Stimulate discussion on how the different organizations affect local people and work with them.
8. Ask the participants what the diagram means to them. How would it look in an ideal situation? What can be done to achieve this ideal?

Notes

There are many ways to use Venn diagrams. They can just show organizations; or they can show all the households in the community and their relationships to the various organizations. For example, you can use small pieces of paper to show the number of people who are members of, or who are served by, certain organizations.

Instead of just "the community", the big circle on the ground can mean "land and water management in the community". See if this makes a difference to the importance of the organizations and how close they are to each other.

Learning objectives

Visualize the major organizations that affect the community.

Identify the links between them and with the community.

Assess how the major organizations function.

Timing

Early in the farmer field school, when land and water management problems and opportunities are being identified.

Preparation

Cut out different sized circles or ovals of paper. You will need as many ovals as organizations (make some extras just in case).

Duration

2 hours.

Materials

Pieces of paper (different colours if possible), marker pens, scissors.

Adapted from

Anyaegbunam et al. (2004)

Exercise 2.5 Wealth ranking

Learning objectives

Understand how local people define wealth and well-being.

Understand the socio-economic situation of different people.

Select indicators to assess the wealth and well-being of people in the community.

Timing

Best done immediately after the resource mapping (► *Exercise 2.1*).

Preparation

Get a list of names of each household in the community from the local authority.

Duration

1–2 hours, depending on size of the community.

Materials

Cards or small pieces of paper, say 10 x 15 cm (1/4 A4 size), marker pens.

Adapted from

Anyaegbunam et al. (2004)

All too often, development efforts benefit the rich more than the poor. Wealth ranking is important to understand the distribution of income and wealth in the community, and to make sure that development efforts benefit the people who need them most.

It also produces a way of showing progress: if the farmer field school results in people getting richer, then it will have been successful. To measure this, do one wealth ranking near the beginning of the farmer field school process, and another several years later, towards the end.

Steps

1. Ask the group to write the names of each household in the community on cards – one household on each card (it may be possible to prepare these cards beforehand).
2. Ask the participants to think of three categories of families in the community: less well-off, average, and better-off. Ask them to say in what ways they are different. On three flip chart sheets, record the indicators they suggest for each category. If they stop, you may prompt with ideas. Besides income, land size or cattle numbers, other possibilities include type of housing, the number of children at school (or who have gone to school), hiring of labour, number of sheep or goats, or ownership of a radio or bicycle. Ask them to agree on five or six things that distinguish them.
3. During the discussion, the participants may identify other socio-economic categories, such as very well-off or very poor. Ask them to name ways that the very well-off are different from the merely well off, and how the very poor are different from the less well-off.
4. Ask a few participants to sort the cards into piles according to which wealth category each household belongs to.
5. Ask another group of participants to check the names in each pile and see if they agree. Discuss any disagreements.
6. The result is an agreed grouping of households with similar natural resource and socio-economic situations. This grouping can be used in analysing problems and targeting of land and water management interventions.

Notes

Wealth ranking is a sensitive subject, and may be taboo. But mostly it is quite acceptable when the ranking is used to identify rather broad categories, such as less well-off, average, better-off. The farmer field school members themselves should propose the factors used to differentiate between the three categories. Treat the results with tact and confidentiality.

Without using cards, the farmer field school members can also group themselves according to their own wealth criteria. That may help them to work out how to divide everyone else in the community into wealth categories.

Exercise 2.6 Gender and socio-economic analysis

This exercise explores the relations between men and women, their rights, roles, responsibilities and identities. Consider other socio-economic differences too: age, ethnicity and social status. Gender does not mean promoting women, but focusing on women in relation to men. This reveals biases in how women (and men) are treated in the culture and by the government.

Men and women typically have different roles and responsibilities. These depend on the household structure, access to and control over resources, the division of labour, and interests and needs. Gender differences affect household security, family wellbeing, planning, production, and many other aspects of life. Women often do a lot of the farming, especially weeding; they also often process, store and sell crops; and look after chickens, sheep and goats, and young animals. Men tend to focus on land preparation for market-oriented or cash crop production, the use of inputs, and caring for cattle.

Don't forget children: boys and girls also may have important jobs in the household and farm. Many families also hire labourers. Many men seek work in towns. Many are sick or have died from AIDS or other illnesses, so much of the farm work falls to women. Ask carefully to find out if the absent men still make important decisions, and record which decisions they make.

Because men and women do different things, they have different skills and know about different things: land and water resources, ecosystems, crop varieties, animal breeds, farming systems and nutritional values of various types of food. This exercise explores who does what, and who knows what.

Learning objectives

Collect information, raise awareness and understand how household and community tasks are distributed according to gender.

Timing

Early in the farmer field school, when land and water management problems and opportunities are being identified.

Preparation

Prepare drawings and cards.

Duration

1 hour.

Materials

Three large drawings of a man, a woman and a couple; cards or small pieces of paper showing farm work, daily household tasks, and community work; blank cards, marker pens.

Adapted from

Jordans (1998)

Steps

1. Put the drawings of a man, a woman and a couple in a row on the ground.
2. Ask the participants to put each of the cards showing agricultural activities and other tasks under one of the drawings. Put a card under the drawing of the man if he normally does that task, under the woman if she does it, or under the couple if both do it. Start off with tasks that are easy to categorize, then go on to more difficult ones. Let the participants take over the exercise and conduct the discussion.
3. Ask the group to analyse the workloads: how much work does each task take, and who does it? Link the tasks and workloads to land and water management activities. Focus the discussion on how women might contribute and what problems they face in doing so.

Questions to stimulate discussion

- How do women and men manage land and water for different purposes: rainfed and irrigated cropping, livestock production, etc?
- Compare what women and men do now to what their mothers and fathers used to do. How have the tasks changed? Why?
- Who (men, women) should be involved in planning land and water management activities?
- Who does what, in families headed by women? In families affected by HIV/AIDS? How are these families different from other families in terms of who does what?
- How are older people different in terms of who does what? How about people from different ethnic groups? Owners of big farms? Landless people? Richer and poorer people?

References on gender

FAO website on gender: www.fao.org/Gender/gender.htm

FAO website on gender and development: www.fao.org/sd/pe1_en.htm

FAO website for gender, agrobiodiversity and local knowledge: www.fao.org/sd/links

Exercise 2.7 Identifying farming problems and constraints

Learning objectives

Identify farming problems and constraints.

Timing

Early in the farmer field school, when land and water management problems and opportunities are being identified, after ► *Exercise 2.1 Resource mapping.*

Preparation

The resource map prepared in ► *Exercise 2.1.*

Duration

1 hour.

Materials

Cards or small pieces of paper, say 15 x 21 cm (1/2 A4 size); marker pens.

Adapted from

FARMESA (2003)

This exercise uses the village map made in ► *Exercise 2.1*. It adds information to the map and analyses resource management and production constraints in more detail.

Steps

1. Using the village map the group prepared earlier as a focus for discussion, ask the group about the land and water management practices used in the community. List all the practices they mention.
2. Choose one of the practices as an example, and ask about the problems and constraints that farmers face with it.
3. Form small groups of 3–4 people each. Each group chooses one or two practices, and thinks of the problems and constraints associated with it. The group writes these problems on cards.
4. Each group then presents its cards to other groups. Put the cards on the floor or on a board for all to see. Encourage discussion during the presentations.
5. After the presentations, ask the group to regroup the problems and constraints into categories. These categories might refer to the slope, soil type, land use, position on the slope (top, middle, bottom), etc.
6. Give a name to each category of problems and constraints.
7. Summarize the main findings of the exercise.

Questions to stimulate discussion

- What are the main problems that women identify? Are they the same as for men? Which problems are the same for everyone?
- What problems do different socio-economic groups identify? Which priority problems did they share? Which problems are related to each other?
- Who has a stake in the management of the land or the watershed? How big is their stake?
- Are there conflicts among these stakeholders? Do partnerships exist between them?
- How do people deal with the problems? What are the effects on women and on men (e.g., do women have to go further to fetch water in the dry season)?

Exercise 2.8 Identifying problems at different times of year

This exercise enables the group to identify problems faced at different times of the year, and to identify the cause of these problems.

Steps

1. Draw a big circle (at least 2 m across) on the ground with the stick or chalk. Divide the circle like a cake into 12 slices, one for each month of the year.
2. For each month, discuss the farming problems that farmers usually face in that month. Write them on cards, and place the cards in the appropriate slices of the circle.
3. Discuss the cause of each problem. (For example, if the problem is dry soil, the reasons might be too little rain, high runoff rates, and so on.) Write the causes on a new set of cards and put them in the appropriate slices of the circle.
4. Summarize the main points of the exercise.

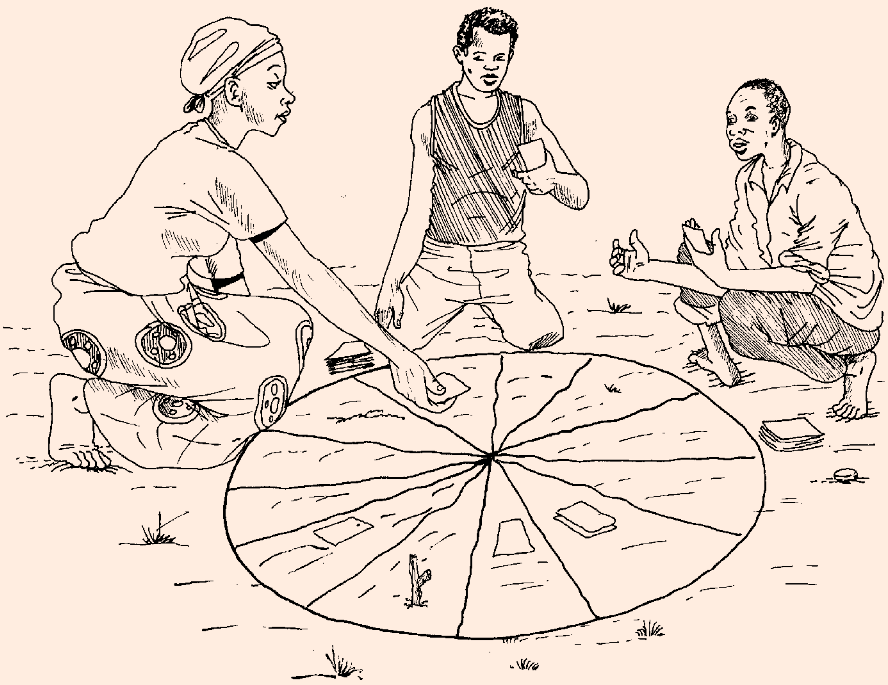


Figure 2.7. Identifying problems at different times of the year. Each sector in the circle represents a month.

2

Learning objectives

Identify problems and constraints that occur at different times of the year.

Timing

Early in the farmer field school, when land and water management problems and opportunities are being identified, after ► *Exercise 2.3 Seasonal calendar*.

Duration

1 hour.

Materials

Cards or small pieces of paper, say 10 x 15 cm (1/4 A4 size); a stick or chalk, marker pens.

Adapted from

FARMESA (2003)

Exercise 2.9 Problem tree

Learning objectives

Understand the causes and effects of individual problems.

Identify the root causes of problems.

Timing

Early in the farmer field school, when land and water management problems and opportunities are being identified, after ► *Exercise 2.7.*

Preparation

Based on the problems identified in ► *Exercise 2.7*, invite relevant specialists to attend the session.

Duration

1–2 hours.

Materials

Pieces of A4 paper; cards or small pieces of paper, say 15 x 21 cm (1/2 A4 size); marker pens, thin sticks (e.g., bamboo canes).

Adapted from

Galpin et al. (2000) and Anyaegbunam et al. (2004)

A problem tree or causal diagram enables farmers to identify the root causes of problems they face, and to judge which of the various causes is most important. That will allow them to identify potential solutions that are likely to work, rather than merely addressing symptoms.

Problem trees and causal diagrams are similar. The main difference is that the causal diagram does not include the problem's effects. This description focuses on problem trees.

The starting point is the list of problems drawn up in ► *Exercise 2.7 Identifying farming problems and constraints*.

Steps

1. Ask the participants to list the main problems they face that are related to soil and water management (this is the output from ► *Exercise 2.7*).
2. Ask the participants to select one of the problems for one of the farming systems in the community. Write it on a piece of A4 paper and put it in the middle of an open piece of ground.
3. Ask the participants to think of what effects the problem has. For example, if "erosion" is the problem, the effects might include "loss of topsoil", "declining crop yields", and "silting of canals". Some of these effects may already have been listed as separate problems in ► *Exercise 2.7*.
4. Ask them to write the effects on cards – one card per effect. Ask them to put the cards on the ground on one side of the paper with the main problem. Use the sticks to show the relationships between the problem and each of the effects. Write more cards and add them to the diagram to show further effects of the effects (e.g., "flooding" as a result of "silting of canals"). Your diagram should now look like the branches of a tree, with the initial problem as the trunk, and the effects as branches and twigs.
5. When the group has finished the effects side, move to the other side of the initial problem. Ask the group to think of the causes of this problem – why it occurs. For example, as causes of "erosion", they might think of "uncontrolled grazing", "heavy rain" and "bare fields".
6. Again, ask the group to write these causes on cards, and to put them on the ground with sticks to link the causes to the problem. You are now putting together the "roots" of your tree.
7. Ask what in turn why each of the causes they have just added occurs. For example, they may say the "bare fields" are caused by "lack of crop seed", "lack of mulch" and "dry soil". Get these ideas written on cards, and ask the group to add them to the diagram.
8. Again ask "why" for each of this new set of causes. Continue adding more cards to the diagram to represent new causes. Make sure that each cause is written only once: you can add sticks to link it to other roots of the tree.
9. When the participants feel that everything has been covered, step back and look at the whole diagram. Ask the participants to make any further changes they feel are needed.
10. Ask the participants to look at the cards at the edge of the diagram, without any identified causes. These are the root causes. If the logic of the diagram is correct, solving these root causes will overcome the other problems. Discuss possible solutions to these root causes with farmers. Which

are outside the farmers' control? Which can they do something about? What solutions can they suggest? For example, for the root cause "poor soils", they might suggest "apply manure" or "grow legumes".

11. Repeat this process for the other major problems identified in ► *Exercise 2.7* that have not yet been covered in this diagram. Make sure they cover all the major land uses in the community.
12. Copy the final diagrams onto paper to make a permanent record.

Notes

Instead of using cards and sticks, the participants can draw on the ground, a blackboard or a large piece of paper. However, that makes it more difficult to change part of the diagram as they are working.

Once the participants know how to do this exercise, you can break them into smaller groups and ask each to analyse one of the other problems identified in ► *Exercise 2.7*. When they have finished, get them to present their diagrams to everyone and explain their reasoning.

A causal diagram is the same as a problem tree, but does not look at the effects of the problem. Follow the guide above, but skip steps 3 and 4.

It should become clear during the session that solving one problem will automatically solve other problems too, perhaps even on other land types.

Many of causes of low productivity stem from the socio-economic, organizational, infrastructural, credit and marketing environments. Consider the causes of these problems too, but focus mainly on the technical issues, as the farmer field school can test ways of dealing with these.

The participants can vote which is the most important problem or cause (► *Exercise 2.11 Individual voting* and *Exercise 2.12 Pairwise ranking*).

Exercise 2.10 Problem analysis chart

Learning objectives

Analyse problems in a systematic manner.

Timing

Early in the farmer field school, when land and water management problems and opportunities are being identified, after ► *Exercise 2.7 Identifying farming problems and constraints.*

Preparation

Based on the problems identified in ► *Exercise 2.8 Identifying problems at different times of year* and *Exercise 2.9 Problem tree*, invite relevant specialists to attend the session.

Duration

Several hours.

Materials

Large sheet of paper, marker pens (or blackboard and chalk), diagrams and charts produced during previous exercises.

Adapted from

Jordans (1998), FAO (2000), and Wilde (2001)

This exercise allows the group to analyse problems the community faces. It shows where the constraints faced by different people overlap, and where they differ. It allows them to discuss the causes of the problems in detail, as well as what people currently do to deal with them. The exercise reveals whether people have already tried to solve a particular problem, and why they succeeded or failed.

The exercise also looks at ways to solve the problems. At least two or three technical specialists from outside, such as extension officers, NGO workers or researchers, should be invited to participate as well. They can make suggestions, and advise whether the farmers' ideas would work. While the group may have very good ideas about what they need, they may not know enough about how to fulfil these needs.

Steps

1. Invite members of the group to review the results of previous exercises, especially ► *Exercise 2.8* and *Exercise 2.9*.
2. Prepare a problem analysis chart (► *Table 2.2*). In the leftmost column, write the main problems identified in the previous exercises. Explain which groups identified which problem, and point out any overlaps.
3. For each problem, write the causes that the group have identified the second column. Ask if anyone, including the outsiders, has anything to add.
4. Ask the group to explain what they currently do to cope with each of the problems. List these in the third column.
5. Ask them to suggest ways to solve each problem. List these ideas in the last column. Give both the farmer field school members and the outsiders a chance to speak.

Questions to stimulate discussion

- Did the outsiders identify extra causes of the problems? What are they?
- What do people currently do to deal with the problems? What are the effects on women and on men?
- How might the problems be overcome? What possibilities did the community members suggest? What did the outsiders say? Which can be done by the local people themselves? Which require external assistance?

Notes

Consider involving the whole community in this exercise. Make sure that different segments of the community are present: men and women, young and old, well-off and less well-off. Before starting the problem analysis, members of the farmer field school should present to the plenary the results of previous exercises.

You may want to fill in the first two columns of the problem analysis chart before the meeting.

You can divide the participants into smaller groups. Ask each group to focus on a particular set of problems or rows in the chart. When they have finished, get them to present their results to the plenary. Summarize all the groups' results in a single chart.

Table 2.2. Part of a completed problem analysis chart

Problems	Causes	Coping strategies (what do people do now?)	Opportunities (what could be done?)
Erosion	Heavy rain, runoff, floods (gully and sheet erosion), wind erosion (loss of topsoil), overstocking of animals, deforestation	None at present	Plant trees and grasses to cover the soil and provide wood Build check dams Divert water away from gullies Control grazing (rotate, fence) to rest pasture Build embankments to control erosion
Water	Lack of piped water, lack of maintenance of pump, shortage of diesel, drought – drying of streams, springs	Fetch water from long distances, contribute funds to maintain pump, migrate to where water is available, use water reservoirs	Lay pipes to carry water downhill Organize for stock of diesel and spare parts for pump Build water tanks to collect water from roofs
Drought	Low rainfall, rain irregular and heavy when it comes, few trees and sparse vegetation	None at present	Protect environment e.g. control burning, plant trees, use mulch, plant drought resistant-varieties, harvest water
…	…	…	…

Adapted from Wilde (2001)

Exercise 2.11 Individual voting

Learning objectives

Prioritize problems.

Timing

Early in the farmer field school, when land and water management problems and opportunities are being identified, after ▶ *Exercise 2.8 Identifying problems at different times of year* and *Exercise 2.9 Problem tree*.

Preparation

Bring the results of *Exercise 2.8* and *Exercise 2.9* to the meeting.

Duration

1 hour.

Materials

Large sheet of paper, marker pens (or blackboard and chalk).

This exercise enables the group to determine the most important problem to address. It is democratic in that it gives each person the same voice as everyone else. This is important to ensure that the richer or more powerful farmers do not dominate the decision making.

Steps

1. Write on the paper, one above another, all the problems identified in previous exercises. If the group can think of any additional problems, add them to the list. Draw a line between each of the problems to separate them.
2. Explain to the participants that they each have three votes. They should vote for the three problems that they think are the most important. They should do this by drawing a vertical stroke (|) next to each of these three problems.
3. Each of the participants then goes individually to the chart to write his or her three strokes next to their priority problems.
4. When everyone has finished, add up all the strokes next to each problem. The problem with the highest score is the one the participants as a whole think is the most important.
5. Review the results to ensure that there is a consensus. Then discuss whether the problems represent the topics they would like to study further and learn about during the farmer field school.

Notes

You can also do this exercise with illiterate farmers using symbols or drawings to represent the problems. Give each person 3 (or 10) stones or dried beans. The individual votes by putting a certain number of stones or beans against each problem: more for serious problems, less (or none) against less important problems. When everyone has voted, count up the number of stones or beans against each problem to find out which people think is the most important.

Another variation is to ask each person to give a score from 1 to 3 to each of the problems: 1 for low priority, 2 for medium, 3 for high. Each person writes a number, 1, 2 or 3, against each of the problems. Add up the scores to get the result.

Exercise 2.12 Pairwise ranking

This exercise enables the group to prioritize the problems and identify which are most relevant for them. It works best if there are no more than five problems to be ranked.

Steps

1. Write on the paper all the problems identified in previous exercises. If the group can think of any additional problems, add them to the list.
2. Draw a table on another sheet of paper. Write all the problems across the top of the table. Write them again down the left side (► *Table 2.3*).
3. Starting with the top row, ask the group to compare each of the problems, one by one, with each of the other problems. Which is more important of each pair? The group can vote by raising their hands. Write the more important problem in the appropriate place in the matrix.
4. When you have finished the first row, go on to the second row, then the third and fourth, until you reach the bottom. Block out half the cells below the diagonal to avoid duplication.
5. Add up the number of times the group thought each problem was more important. The most important problem overall will have the highest score. In ► *Table 2.3*, poor soil fertility is mentioned as "more important" three times, so is the most important problem.
6. Write the problems in order of importance on a new sheet of paper.

Questions to stimulate discussion

- Are there any problems missing from the list?
- Are there any problems on the list that are closely related or can be considered the same?
- Are there problems that are specific to a certain area or group of farmers (e.g., on a slope, on a specific soil type, in a certain farming system)?
- Does the final list of priorities reflect what the group would like to learn more about and experiment with?
- On what basis did the group decide on the importance of the problems?
- Are there problems on the list that are very closely related to one another?
- Do the group members agree with the final priority list?
- Are all the problems relevant to everybody in the group, or are different problems relevant to different farmers?

Notes

You use pairwise ranking in many other ways too: to choose which technologies to test (► *Module 3 Innovation and experiments*), evaluate different service providers, decide among several solutions to a problem, or evaluate technology alternatives.

Consider also using individual voting (► *Exercise 2.11*) or matrix scoring (► *Exercise 3.4*) to choose among different alternatives.

Learning objectives

Prioritize problems.

Timing

Early in the farmer field school, when land and water management problems and opportunities are being identified, after ► *Exercise 2.8 Identifying problems at different times of year* and *Exercise 2.9 Problem tree*.

Preparation

Bring the results of ► *Exercises 2.8* and *2.9* to the meeting.

Duration

1 hour.

Materials

Large sheets of paper, marker pens.

Adapted from

FARMESA (2003)

Table 2.3. Example of pairwise ranking: Ranking of problems causing low yields

	Lack of water (W)	Poor soil fertility (F)	Pests (P)	Striga weeds (S)
Poor soil fertility	F			
Pests	W	F		
Striga weeds	W	F	P	
Times mentioned	2	3	1	0
Rank	2	1	3	4

Exercise 2.13 Identifying possible solutions for testing

Learning objectives

Identify possible solutions that can be studied and tested in a study plot.

Timing

Early in the farmer field school, when land and water management problems and opportunities are being identified, after ► *Exercise 2.10 Problem analysis chart*.

Preparation

–

Duration

2 hours.

Materials

Large sheet of paper, marker pens.

Adapted from

FARMESA (2003)

The previous exercises identified and prioritized various farming problems. This exercise helps the group think of possible solutions to these problems.

The exercise helps the group determine what practices are currently used, what their benefits are, and what inputs these practices require. The group should also be able to draw on training they have had and their own experience to identify new practices to test.

Since the group may not know about new technologies, you may also want to invite an outsider who knows about such things to this session (if you do not have this background yourself).

The group should think of the work, materials and money that each of the possible solutions would need. That will show if the practices are suited to local conditions.

Steps

1. Divide the paper into a table with five columns and as many rows as you need. Write the following at the top of each column: Problems; Physical conditions; Inputs available; Inputs needed; Possible solutions (► *Table 2.4*).
2. In the "problems" column, ask the group to write the main problems they have identified in earlier exercises.
3. Discuss one problem at a time. In the "physical conditions" column, ask them to write things like the slope, soil type, and climate that are relevant to that problem. In the "inputs available" column, ask them to write what materials and other inputs are available that might be used to deal with the problem (e.g., cash, labour, stones, manure).
4. Then get them to identify possible solutions to the problem, considering what is written in the first three columns. Write this in the last column. Ask them to think of what inputs they still need, if anything, and to write this in the "inputs needed" column.
5. Then move onto the next problem. Go through each problem until you have a list of possible technologies to test.

Table 2.4. Example of a solutions matrix

Problems	Physical conditions	Inputs/material available	Inputs needed	Possible solutions
Soils hold little water and dry out quickly	Shallow and sandy soils	Manure Dry plant materials	Shade for compost Donkey or oxen for transport	Compost to improve the soil structure and water holding capacity
Much soil moisture is lost through evaporation	High temperatures and uneven rainfall distribution	Animal draft Cash to buy farm inputs	Supplier of conservation agriculture tools and equipment Seeds of cover crops	No tillage or minimum tillage and mulch to conserve moisture
Rainwater is lost through runoff and soils are eroded	Gentle slopes	Stones and labour	Community organization Food for work for catchment-scale work	Stone lines along the contour to slow runoff and reduce erosion

6. When the group has finished, step back and look at the list of possible solutions. Discuss the following questions:

- Have all the main problems and possible solutions been included?
- Is there overlap among the various solutions? Can any be combined? In the case above all three practices should be combined for best effects
- Are these solutions realistic in the current situation?
- Which of the possible solutions would the group like to test in the field?
- What is needed to put these solutions into practice?

7. Decide which three or four solutions to test in the farmer field school. You can use the prioritization methods (► *Exercise 2.11 Individual voting* or *Exercise 2.12 Pairwise ranking*) to do this.

Notes

To make sure that all the possible solutions are discussed, try breaking the participants into smaller groups of 4–5 participants each. They should present their conclusions and suggestions for discussion by the plenary. Try to get agreement among the participants on the final list of solutions.

Module 3. Innovation and experiments

Farmers try out new ideas all the time. This is an important part of the process of developing and spreading innovations. Innovation and experimentation are a vital part of the farmer field school process: it gives farmers a chance to learn and build their capacity to adapt to change and improve how they manage their resources.

Farmers usually innovate (change what they do and how they do it) to solve problems. Farming situations are very diverse and complex: each one is unique. Agricultural research by itself cannot create all the technologies that farmers need. That means farmers, researchers and extension staff must work together to solve problems. Farmer field schools are a good way to do this. Farmers in the farmer field school can learn about and test the results of new research, while the researchers can draw on the farmers' experiences and learn about the constraints they face.

This module explains how to test the opportunities the farmers have identified in ► *Module 2 Improving land management* to see which ones work best.

Learning objectives

After studying this module, you should be able to:

Understand how to build on local knowledge and farmer innovations.

Understand the concept of farmer experimentation and how it fits in farmer field schools.

Plan, design and implement study fields and experiments in farmer field schools.

Monitor and evaluate study fields and experiments.

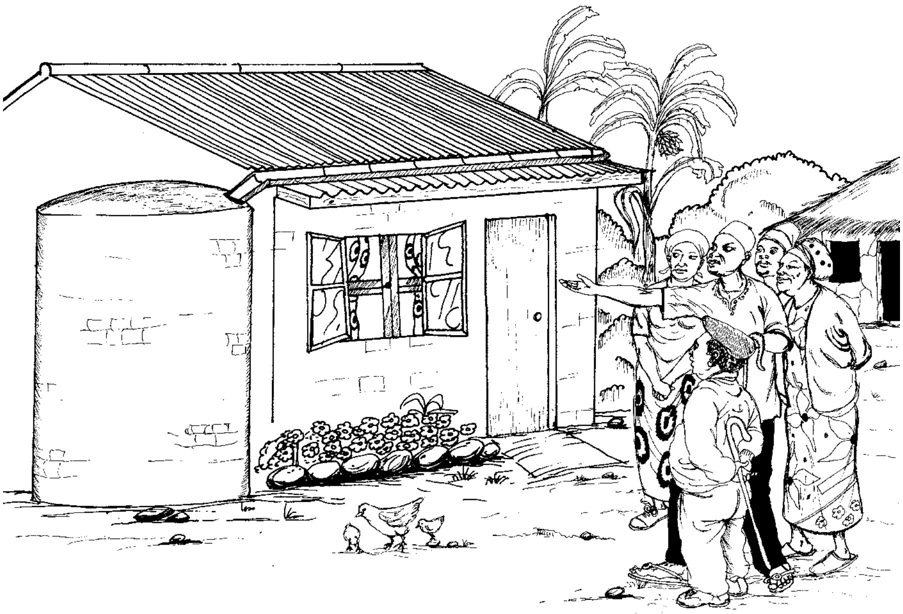


Figure 3.1. This module shows how to encouage farmers to learn from real-life experiments they do themselves.

Building on local knowledge and innovations

Farmer innovation is how farmers normally generate, adapt or adopt new ideas, approaches and technologies. They do this to deal with specific challenges or to improve their management practices and enterprises. It is important for the development and spread of new technologies. Indeed, it is the main way that advances in technology have been made in agriculture over generations worldwide.

Farmer innovators are farmers (or other land users) who test new methods on their own initiative, often using ideas from various different sources.

Farm innovations may be techniques that have already been tried and found to work somewhere else and newly introduced to the area/community. Or they may be new – perhaps an adaptation of an existing method – but still need testing and adaptation before they can be used more widely.

Farmer innovators, and many of the most remarkable innovations, are often found in remote areas. In such areas, there are few services such as extension or research, so farmers have to resort to their own testing and adaptation (experimentation).

Integrating farmer innovations in the farmer field school process

Researchers and development workers often overlook farmer innovations – seeing them as inferior to formal, research-based technologies. But blending local innovations and science-based knowledge may be the best way to improve production in a sustainable way. Farmer innovations can be a valuable source of practices that other farmers can adopt and adapt. Farmer innovators are inquisitive and knowledgeable. They are often a storehouse of ideas, and provide a direct, quick entry point to the community.

Here are some ways to harness farmer innovations:

- Collect information on the farmer innovators in the community.
- Visit the innovators to check whether their innovations could benefit other farmers.
- Collect basic information on the innovators and their innovations.
- Train selected innovators to increase their communication skills and ability to share their innovations with others.
- Facilitate interactions between the innovators and nearby farming communities.
- Arrange forums for innovators to interact, learn from and inspire each other.
- Here are some ways to integrate farmer innovations in the farmer field school process:
- Recognize innovators and integrate them into the farmer field school as members and resource persons.
- Invite innovators to give presentations during special topic sessions.
- Arrange visits to innovators' farms and ask them to explain what they have done.
- Include farmer innovations among the practices to be studied in the farmer field school.
- Document and disseminate information about innovations.

► *Exercise 3.1 Identifying local innovations.*

Experimentation in farmer field schools

Experiments in farmer field schools do not have to be complicated or risky, and farmers can do them themselves even if they do not have formal education. The experiments enable farmers to learn new ideas, test them and find whether they work in their conditions. The farmers and the farmer field school facilitators (extension staff or researchers) play different roles in the experiment (► *Box 3.1*).

Planning comparative experiments

Experiments usually involve several steps, including planning, design, implementation and evaluation. Good planning is needed to be sure that the experiment will tell you what you want to know.

Selecting a learning theme

Before you choose what to study in the experiment, make sure you understand the problem. This should be based on what the farmers see as their most important constraints and opportunities. ► *Module 2 Improving land management*

Setting objectives

An experiment must have clear objectives. Formulate these objectives jointly with all the farmer field school members, facilitators and researchers. Use these questions to help you:

- What do we want to learn from the experiment?
- Why do we want to experiment with the new technology or practice?

Selecting options

The farmers, facilitators and researchers then propose what technologies or practices to test, based on the possibilities identified earlier. They discuss each possibility, perhaps in smaller groups (men, women, young people to make sure everyone can express their opinion), and prioritize them by voting (► *Exercise 2.11*) or using pairwise ranking (► *Exercise 2.12*). This should help everyone agree on the technology (or technologies) for the farmer field school to test.

Things to consider when choosing what to study:

- How likely is it that the technology/practice will solve the problem?
- What benefits might it bring – in terms of profitability, lower risks, equitability, less drudgery, benefits for women?
- How easy is it for people to adopt?
- How easy will it be to study – in terms of the resources and management needed?

Choosing the study site

Where to do the experiment? The site should be typical of the local farming situation. For studies on crops, soils and water, it is usually on the farm of one of the farmer field school members. This "host" farmer must volunteer to provide a suitable piece of land to use. For livestock studies, it may be necessary to use several different farms, depending on the type of study. Some farmer field schools also use land made available by a church, or by someone else who does not use all of his or her land. Make an agreement with the land owner first on where to do the experiment and how long it will last.

Factors to consider in choosing the experimental site:

- The site should be typical of the local area.
- The host farmer must be motivated, interested and committed.

Box 3.1. Complementary roles of farmers and farmer field school facilitators in farmer field school experiments

Farmers

- Know their priority problems
- Know the local situation
- Know their own possibilities and capabilities
- Have good observational powers
- Know local diversity of farmers and farming contexts

Extension staff or researcher

- Identify hidden technical constraints (researchers advise if needed)
- Have experience in research
- Use formal analytical methods
- Know different farming situations elsewhere

Both

- Are sources of ideas for solutions to problems
- Assess feasibility of various options
- Are inquisitive observers and experimenters

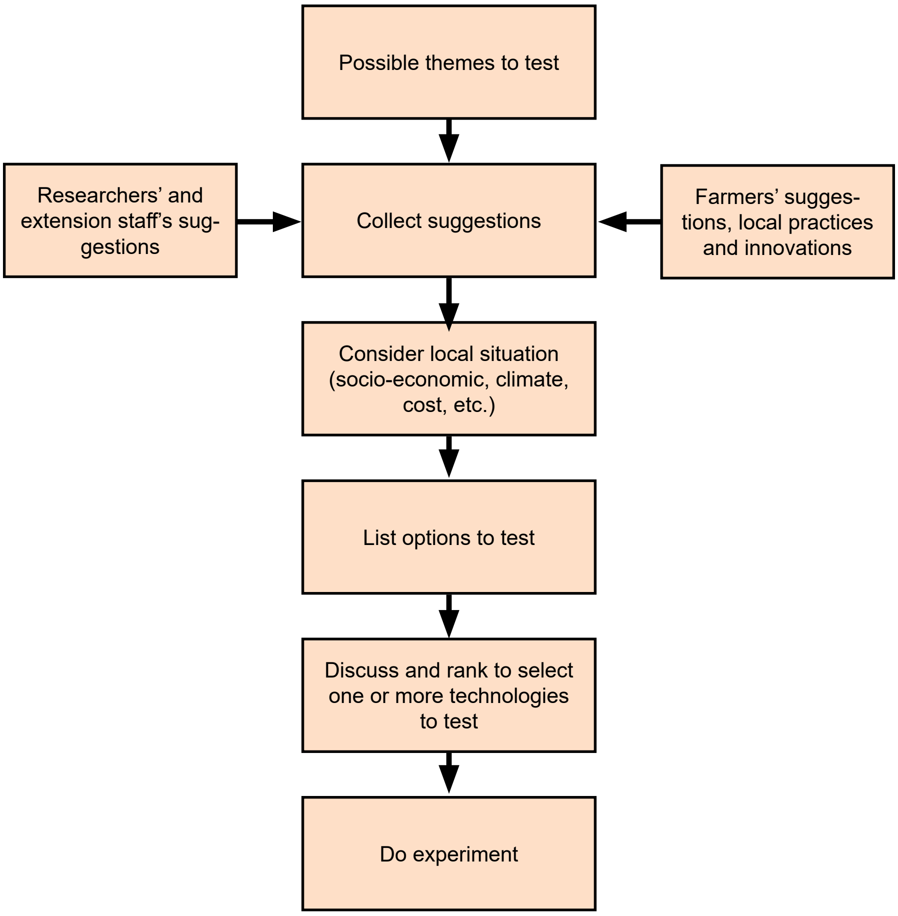


Figure 3.2. Steps to match farmer field school members', facilitators' and researchers' technology options for testing

Box 3.2. Questions when planning comparative experiments

- What is the problem we want to solve?
- What is the objective of the experiment?
- What opportunities exist to address the problem?
- What technology do we want to test?
- What resources are needed to do the test?
- What treatments do we include in the experiment?
- Where do we implement the experiment?
- What indicators should we use to know if it has succeeded or failed?
- How do we monitor and evaluate the experiment?

- The field must be safe from animals, fire, etc.
- The land must be large enough, and must be the right type for the technology being tested.

Options to test

The next step is to decide on the alternative practices the group wants to study compared to the traditional/ normal practice. There may be ideas from research, or there may be farmer innovations or local practices. The alternative practices to compare are known as "treatments". The treatments are usually chosen through group discussions, where possible with advice from extension or research – but take care to keep it simple!. Some questions that may help in designing treatments:

- Which practices do farmers want to compare?
- Which are comparable and useful to compare?
- What variables (factors) are the farmers especially interested in?
- What resources are needed to do the experiment?

There can be two or more treatments in an experiment.

One of the treatments in an experiment is known as the "control". This is generally the practice that the farmers usually use. All the other options are compared to it. For example, the farmers can compare the alternative treatments in terms of yield, cost, labour needed, and so on, with the control. Including a control shows whether the alternatives produced exceptionally good (or bad) results just because of good (or bad) weather in that season, or some other factor. As we are encouraging farmers to look at beneficial interactions in the ecosystem, one treatment can be a single practice, another treatment may be a combination of two practices, and the third treatment a combination of three improved practices.

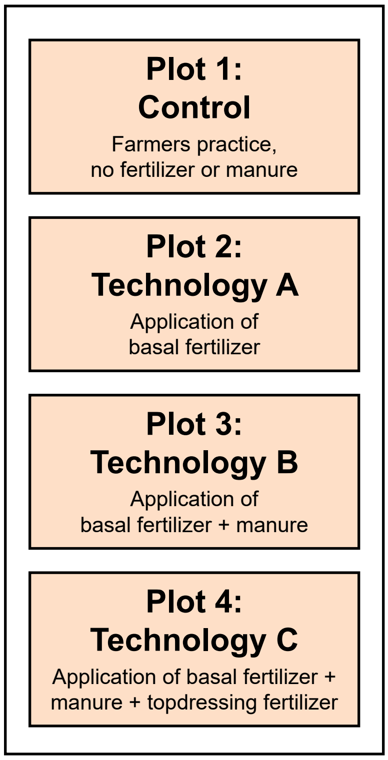


Figure 3.3. Example of experimental plot layout

Potential problems

Many experiments are not well designed or sited, which leads to misleading results. Three examples:

Poor design. The treatments compared may not be useful to compare. For example, supposing we want to compare the benefits of different types of fertilizer. We might decide on three treatments:

- Artificial fertilizer
- Manure
- Legume or green manure

But every good farmer knows that the soil requires a combination of practices: the fertilizer provides plant nutrients, manure restores the soil structure and organic matter, and the legume or green manure protects the soil cover and fixes nitrogen. See below for some alternative suggestions, and ▶ *Module 7* for more.

Non-representative site. The test field (or part of it) may have very shallow soil. If that is typical of the area, that is OK. But if it is not typical, the results of the experiment might not be applicable on other farms in the area. If part of the site has a shallow soil, the crops grown there may perform poorly, giving misleading results.

Risky location. If the test field is poorly chosen, it may be subject to erosion, flooding, grazing by animals attacks by pests, burning, etc. That could mean wasting a year's effort in the experiment!

Choosing the crop or livestock

In crop-based experiments related to soil and water management, the group should choose one crop or a specific crop combination, to test under various management practices. Farmer field schools that focus on increasing income may wish to use a high-value crop. Or they may want to test a staple crop, but also plant a second plot with a high-value crop to earn money for the farmer field school. In livestock-based experiments, it is best to choose just one animal species and breed, and have several animals in each treatment.

Keeping treatments simple

Keep the treatments as simple as possible. Minimize the number of factors (things to study) and the levels of each factor. In crop-based experiments, you can keep things simple by:

Studying different levels of a single factor. For example:

- Farmers' practice
- Compost applied at a rate of 1000 kg/ha
- Compost applied at a rate of 2000 kg/ha

Including more than one factor in a **stepwise arrangement** (add-on options). For example:

- Farmers' practice
- Compost (1000 kg/ha)
- Compost (1000 kg/ha) + mulch (1000 kg/ha)

Apart from the factor you choose to study, everything else should be kept the same for the various plots. So, for example, prepare the land on all the plots in the same way, plant on the same date, weed the same way on the same days, and harvest at the same time. If the study plots have too many different factors, it will be very difficult or impossible to see the effects of the treatments you have chosen.

Dealing with variability

Variability is one of the major problems in experiments. No one field or growing season is exactly like another. That means it is important to identify what causes variability. In crop-based tests, it may be caused by soils that vary from plot to plot, different slopes, different management practices and crops grown in previous seasons, shade, proximity to anthills or tree stumps, and so on. In livestock tests, animals may be of different breeds and ages, or they may have been fed differently before the start of the experiment, and they may be healthy and well fed, or poorly fed and infested with parasites.

There are several ways to deal with variability. Here are two:

Replication. This means repeating each treatment more than once. So instead of one plot (or animal) for each treatment, there are several. How many times should you repeat each treatment? This will depend on the objectives of the study, how much land (or how many animals) are available, and how much time and money is available. If more than one farmer hosts the tests, perhaps each of those farmers can manage a complete set of all the different treatments. In addition other field members can try certain practices.

Uniform management. Try to avoid introducing unwanted variability. Manage all the plots (or animals) the same way: same crop variety, same planting and weeding practices, and so on. Do not put one treatment on a slope and another on flat land; and if there is a slope in the field, arrange the plots side-by-side across the slope. This avoids a plot uphill affecting one downhill e.g., through runoff.

Plot size

For crop-based studies, how big should the plots be? This depends on:

- Practical considerations such as land availability and security.
- Ease of management, amount of labour available, etc.
- Avoiding variability because of slopes, different soil types, etc.
- The type of study. For example, a test of soil conservation measures or improved grazing may need a bigger plot than a test of crop varieties.

Marking plots

Make sure the plots are marked well – with signs or colours – to make them easy to identify. The plots can be separated by paths or marked by stakes at the edges.

Figure 3.4. It is important to repeat (replicate) experiments in several places in case one experiment goes wrong or gives misleading results

3

The plants nearest the edge of the plot may yield especially well (or poorly) because they have no other plants around them so they get more light (or may be damaged by people or animals). When measuring yield and other plant characteristics, do not choose plants nearest the edge of the plot.

Calculating how much manure to apply in an experiment

How much manure (or fertilizer or compost or mulch) should you apply in an experiment? It's important to be realistic – so a good start is to work out how much manure the farmer might be able to apply.

You can adapt the approach below for other calculations, such as working out how much compost to use, how many seeds to sow, or how much fertilizer to apply.

1. Work out how much manure it is realistic for a farmer to apply to one hectare of land

This will depend on many things – the amount of manure and land available, the type of crops planted, the distance from the kraal or stable to the fields, and so on.

Example: Glory Mwanga has four cows, which produce about 10 kg of manure a day, or about 3,500 kg per year. She has 1 ha of land. That means she is able to apply 3,500 kg of manure per hectare.

1 hectare	=	10,000 square metres

So Glory can apply 3,500 kg of manure on 10,000 square metres, or 0.35 kg of manure per square metre.

2. Work out the area of the pot or plot.

Example: Glory wants to compare the effect of manure on her maize yields. She can set aside a plot measuring 10 m x 20 m (= 200 square metres) for the experiment. Half of this (100 m^2) will be with manure, and half without. How much manure should she apply on the 100 m^2 plot?

For the 100 square metres with manure, she will need 100 x 0.35 = 35 kg of manure.

Example: Glory also wants to do a pot experiment to check the effects of manure. She wants to apply the same rate of manure as in her plot experiment. She has several buckets she can use as pots; each bucket measures about 35 cm across, or about 100 square centimetres in area. How much manure should she apply per bucket?

100 square centimetres	=	0.1 square metre

0.1 square metre	x	0.35 kg/m^2	=	0.035 kg	=	35 grams of manure per bucket

Experimenting with livestock

Experiments with cattle are difficult because each animal is very valuable, and farmers do not want to risk even a small a drop in productivity. This is less of a problem with sheep, goats and poultry, though you should try to avoid risk anyway, as most farmers have only a few animals. The more risky themes identified during the diagnosis process could be covered during the farmer field school "special topics" sessions.

Here are some examples of less risky experiments on livestock.

- **Crop–livestock interaction**. Fodder production is important for farmers who keep livestock. They may be interested in doing tests on improved fodder, pasture production and livestock feeding.
- **Comparing existing farmer practices**. The farmer field school could visit farms belonging to members or non-members to observe traditional and new livestock management practices.
- **Comparing improved practices with past farmer practices.** The farmer field school may decide to test improved practices on selected members' farms, and compare them with records from the past for the same farms or under similar situations. Examples include milk production in cows under improved feeding practices, and weight gain of cattle under different management systems.

► *Module 9* for more information on livestock.

Comparative studies without doing experiments

For some topics, it can be difficult to set up comparative experiments: it may take too long, or they might need too much land or cost too much. A way of getting round this is to find examples of treatments already in place, and compare these with each other.

For example, the group might decide to test how land use affects soil erosion. It might not be feasible to set up plots with different land use, such as pasture and forest. Instead, the group might identify a nearby forested area, one that is farmed, and a third area that is used as pasture. These three areas should have similar soils, altitudes and climate. The group can then monitor these areas to compare the vegetation cover, amount of runoff and erosion, the soil quality, and the depth of moisture after a rainfall. They could also compare the annual productivity:

- **Crop productivity** = annual yield or value, minus inputs

- **Livestock productivity** = annual yield or value from offspring + meat + milk + hide, minus inputs
- **Tree yield** = yield or value from wood + other products, divided by number of years to reach maturity

Monitoring and evaluating experiments

To tell whether one set of practices/treatment is better than another, it is necessary to monitor and observe differences between them. The farmer field school should check the test plots or animals regularly to see how they are performing. They should observe or measure certain characteristics or "indicators" (see below). Monitoring usually involves collecting and analysing data to show progress or constraints and recording decisions that were made (time of weeding, etc.).

Before the start of the experiment, the group should make a plan on how to monitor it, and who will be responsible for what. ► *Module 16 Assessing impacts, learning lessons* for more information on how to make a monitoring plan.

Deciding on indicators

Indicators are needed to monitor progress. Indicators are things to observe or measure. They show the changes that take place during the experiment (► *Table 3.1*).

What indicators to choose? That depends upon the experiment's objective. The whole group should be involved in deciding what indicators to monitor, and everyone should understand exactly what to monitor and how. Inputs from extension staff and researchers are often useful in this decision.

Table 3.1. Examples of indicators for monitoring crop–soil experiments

What we want to know about	What to observe or measure (indicators)
Nutrient supply, soil fertility	Signs of nutrient deficiency (e.g., yellow leaves), height of crop, yield, number of weeds (competition for nutrients)
Water supply to the crop	Depth and amount of moisture in the soil, surface crusting or sealing, crop wilting, rooting depth
Restriction in root growth	Depth of roots, bending of roots, soil resistance (hardness to dig/till)
Seedling emergence	Crusting of the soil, number of plants per square metre
Soil biological activity	Number of earthworm casts, numbers of earthworms, large pore spaces
Erosion	Number and size of rills, gravel/stony surface, root exposure, amount of silt deposited upstream of an obstruction (e.g. tree) or on flat areas
Crop growth and yield	Crop height, plant vigour, number of leaves, female flowers, number and size of fruits or cobs, length of panicles, crop yield
Pests and diseases	Presence of pests and diseases, extent of damage, number and type of natural enemies
Socio-economic criteria	Amount of labour needed, work done by men and women, profitability
Livestock	Amount of manure produced, weight gain, milk yield, length of time between births

Help the farmer field school members choose indicators by asking the following questions:

- What will show that the new technology is performing well? (This will give indicators of success.)
- What will show that the new technology is performing poorly? (This will give indicators of failure or potential constraints.)
- What other factors are likely to influence the outcome of the experiment? (This will give environmental-related indicators such as rainfall, pest and disease attack, or weed density).

Frequency of monitoring the experiment

It's important to monitor the test plot or animals regularly. But how often? That depends on the type of experiment and the indicators chosen. Discuss with the farmer field school members and reach agreement on what to do.

► *Exercise 3.2 Selecting indicators.*

Agro-ecosystem analysis as a monitoring tool

Monitoring can be done using many different methods. Some of these are explained in more detail in ► *Module 16 Assessing impacts, learning lessons*.

The cornerstone of the farmer field school methodology is **agro-ecosystem analysis**. The farmers observe the agro-ecosystem – the soil, water, crops, pests, etc., in the field – interactions with livestock and analyse the relationships between them.

In this way, the farmers to learn to make regular observations, analyse problems and opportunities they encounter, and improve their decision-making and farm management skills. By doing this analysis regularly in the farmer field school, the farmers develop a mental checklist of things to observe in their own farms.

Here are the main steps in agro-ecosystem analysis:

Table 3.2. Examples of frequency of monitoring of common indicators in crop-based trials

What to observe or measure (indicators)	When to measure
Previous land use, slope, existing soil and water conservation structures, soil type, land area, date of planting, germination rate	At start of the experiment
Signs of erosion, soil cover, nutrient deficiency signs, soil life	Periodically through agro-ecosystem analysis
Rainfall, plant growth, pest and diseases, soil moisture, moisture stress, management practices carried out, labour input	Frequently through agro-ecosystem analysis
Plant height, surface leaf area, health (signs of deficiencies or water stress)	Regular intervals (e.g. 6 weeks after planting, before tasselling).
Plant weight, grain yield, biomass yield, soil nutritional level, total labour input, cost/benefit analysis	At end of experiment
Livestock weight, growth rate, milk yield, cost/benefit analysis	Frequently, also monitor pasture/food quality, and at end of experiment

- **Make observations in the field**. Small groups of farmers observe the indicators in the field. The emphasis is on observing how the soil, crop and environment (or animals and the environment) interact.
- **Make records**. Each subgroup summarizes its findings on a recording sheet (► *Table 3.3*). This includes summary information, pictures and drawings of the plants and insects they have observed, and the subgroup's decisions and recommendations.
- **Present to the whole group**. Each subgroup presents its results and conclusions to all the farmer field school members.
- **Plenary discussion and decisions**. The whole group analyses and discusses the findings of each of the subgroups. The group decides what to do to address any problems that have been observed in the field.

► *Exercise 3.3 Agro-ecosystem analysis for crops.*

Note: The indicators on the sheet depend on the location, objective of the experiment, and subject of study

Figure 3.5. Observe in the field

Figure 3.6. Make records

Figure 3.7. Present to the whole group

Figure 3.8. Plenary discussion and decisions

Mobile or rotational agro-ecosystem analysis

A variation of this exercise can be done when the group members visit individual members' farms. This is common in, for example, experiments with livestock and on soil and water management. It is also useful if the farmer field school plots have no crops growing (e.g., during the dry season), or if the experiments have failed (e.g. due to drought or if animals have broken into the test plots).

In this case, the group does the analysis in different farms each week, one after another in turn. The group studies each place regardless of the crops being grown, but focusing on the management practices. They make observations on that farm, and make recommendations for the host farmer to consider. The other members can also help the host farmer with some of the work – mulching the field, digging a drainage canal or treating a pest problem.

Evaluation

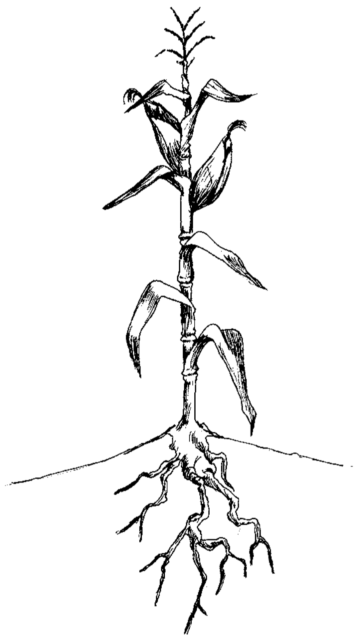
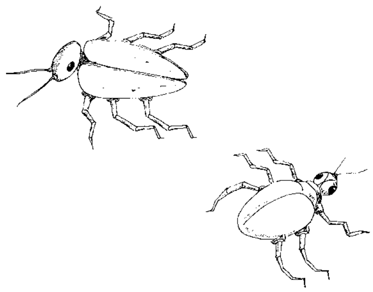
At the end of the experiment (usually at harvest), the farmer field school evaluates the experiment:

- Has the experiment achieved its objectives?
- What causes the differences between the technologies that have been studied?

Matrix scoring and ranking (► *Exercise 3.4*) can be used to help the farmers decide what they think about the different technologies.

► *Module 16 Assessing impacts, learning lessons* for more on evaluating technologies.

Table 3.3. Example of crop agro-ecosystem analysis sheet

Experiment information Name of farmer field school Agro-ecosystem analysis no. Group no. Plot no.		Problem addressed Date Week no. Time of observation
General information Variety Date planted Age of crop (days) Fertilizer Weather Rainfall (mm)	**Plant information** Height of plant (cm) No of leaves No of diseased leaves No of dead leaves	**Soil** Level of soil moisture Soil temperature Hardness of soil surface Labor input
Plant observations Plant types/associations Plant health Plant diseases Insect pests and predators Deficiency symptoms Weeds	**Plant drawing** 	Insects observed on crop or soil Types and numbers 
Soil observations Soil moisture: Soil surface cover: Soil organic matter Soil life Soil erosion/sealing		**Recommendations** What management practices should be applied?

Exercise 3.1 Identifying local innovations

This exercise helps the farmer field school members identify local innovators and use farmers' innovations and experiences to generate ideas on things to study. It also helps them gain confidence in testing and experimentation.

Steps

1. Ask the farmers to list all new technologies and farming practices that they have encountered in the village. Think of both technologies introduced by research and practices developed by farmers.
2. Ask how many farmers have adopted these technologies. Why have they adopted (or not adopted) each one?
3. Discuss the reasons the group names. Possible reasons include different conditions from place to place, financial constraints, skill requirements, soil differences, labour and input needed, etc.
4. Ask who the innovators are in the area. Ask the group to identify the characteristics of farmers who experiment on their own with new practices.

Questions to stimulate discussion

- Researchers develop new practices mainly by doing experiments on research stations or fields they control. Does this affect whether farmers adopt the technology?
- How do farmers in the village exchange information? What types of information do they exchange?

Learning objectives

Discuss research and new technology development in the local area.

Identify local farmer innovators.

Determine factors that affect farmers' adoption of new practices.

Timing

Before the cropping season, after the participatory diagnosis (► *Module 2 Improving land management*). The results can be used to design experiments.

Preparation

–

Duration

1 hour.

Materials

Large sheet of paper, marker pens.

Adapted from

FARMESA (2003)

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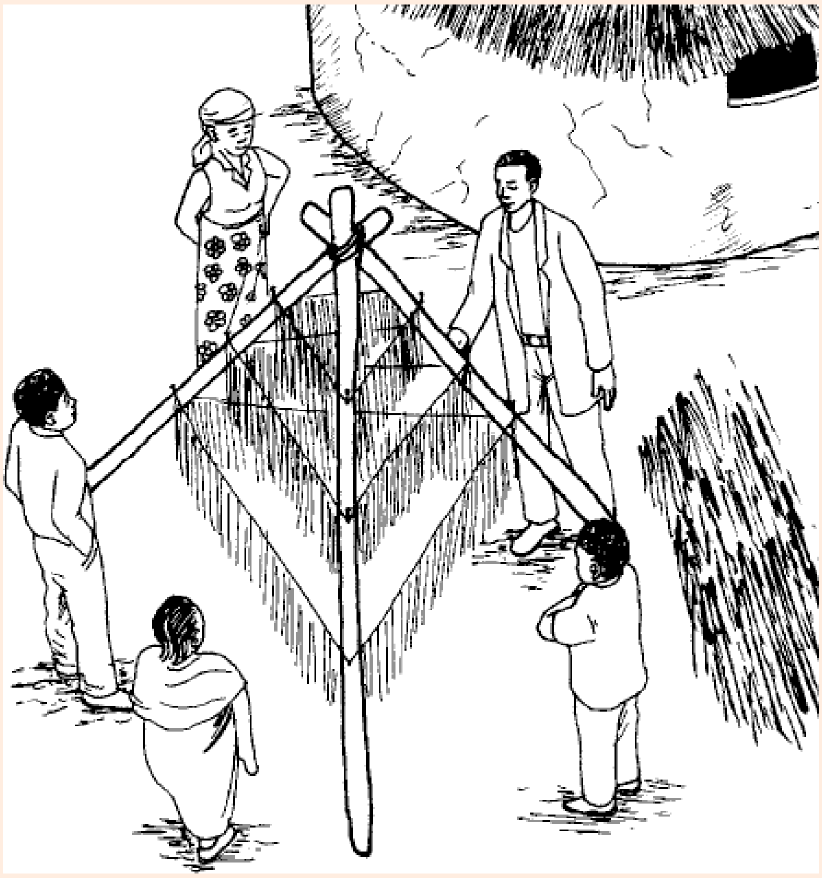


Figure 3.9. Learning about a farmer's technology

Exercise 3.2 Selecting indicators

Learning objectives

Identify measurable indicators.

Determine how to collect and present data.

Timing

Before the cropping season, after the participatory diagnosis (► *Module 2 Improving land management*). The results can be used to monitor experiments or field studies. For livestock, either the dry season or the wet season, or both (a full year).

Preparation

–

Duration

1 hour.

Materials

Large sheets of paper, marker pens.

This exercise helps farmers to select some indicators to monitor their experiments and to decide how to keep and present the data they gather.

Steps

1. Ask the farmers to divide into subgroups of 3 or 4 people. Each group discusses what items they think should be measured during the experiment (yield, labour needed, crop health, soil moisture, etc.). The groups brainstorm ideas and list everything that comes to mind.
2. For each item, the subgroups discuss how to measure it (e.g., for yield, kg of output; for plant growth, height of plant; for labour needed, time spent working in the field)
3. A representative of each subgroup presents the results. Put the lists on the wall so all can see.
4. The whole group looks at all the lists of items, and chooses the ones that are most suitable and easiest to measure. The group also chooses the best way to measure each one. One or two indicators for each item should be enough.
5. Decide on when the measurements should start, how often to make them, how to keep records, and how to share the information among the group.

Questions to stimulate discussion

- Do the indicators measure what they are supposed to? Are they easy to measure?
- How often should they be measured?
- Which part of the field will be used to compare the test practices against the current practice?

Exercise 3.3 Agro-ecosystem analysis for crops

This exercise guides farmers through collecting and analyzing information about the agro-ecosystem in their fields. By analysing what they find, the farmers can decide how to manage their crops and related farm enterprises.

Steps

1. Explain the relationships and linkages between different parts of the farm enterprise (different crops, livestock, soils, water, pests, etc.) that affect the topic of the experiment.
2. Divide the farmer field school members into subgroups, and assign a study field for each group.
3. Guide the groups to collect the information required using the record sheet. Ask them to note important factors that affect production. They should make a list of important observations and recommendations.
4. Each subgroup reviews the information they have collected, and proposes appropriate management practices. For example, if they see a lot of weeds, they might propose weeding. Each group summarizes its findings onto one sheet. Keep the drawings simple.
5. In plenary, each subgroup presents its findings. Make sure a different member of the subgroup does the presentation each week.
6. Invite the farmers to discuss the group presentation and its suggestions. They should agree on what to do, and who should do it.

Questions to stimulate discussion

- What changes can you see since the last time you checked the field?
- What should you do as a result of what you see?

Learning objectives

Identify different components of the agro-ecosystem and their importance.

Collect and analyse field data.

Improve management decisions.

Timing

At every farmer field school session during the cropping season. For perennial crops and looking at effects of rotations or land and water management practices, several seasons may be necessary, and the frequency of the exercise may vary with the seasons.

Preparation

Before starting the exercise, discuss and prepare an agro-ecosystem record sheet with the group.

Duration

2 hours.

Materials

Record sheet, notepaper, pencils.

Exercise 3.4 Matrix scoring

Like individual voting (► *Exercise 2.11*) and pairwise ranking (► *Exercise 2.12*), matrix scoring is a way of ranking various items or alternatives. It allows you to evaluate each item according to various criteria.

Learning objectives

Compare various items or alternatives.

Discover how many people prefer one option over another, and why.

Timing

At any time during the farmer field school cycle when it is necessary to choose among different items.

Preparation

–

Duration

30 minutes.

Materials

Large sheet of paper, marker pens (or blackboard and chalk).

Adapted from

Bayer and Waters-Bayer (2002)

Steps

1. The group makes a list of the items to compare. For example, they may decide to compare the suitability of various types of trees for planting on bunds or along contours across the slope. Write each item (each type of tree) in the first column of a table (► *Table 3.4*).
2. The group next discusses the criteria or factors they want to judge the items against. For example, they may choose the following criteria for their list of trees: value for fixing nitrogen, production of fruit, production of fodder, production of wood, ability to control erosion. They write each of these criteria at the top of a column in the table.
3. Decide what will be the maximum score – such as 5 for "best", 4 for "very good", etc., down to 0 for "bad".
4. Give scores for each item. The group should agree on the score to give the criteria for each item. Write this number in the appropriate place in the table.
5. Count up the total scores for each item. Write this number in the final column in the table. The item with the highest score is the one that people most prefer.

Table 3.4. Example of matrix scoring: different types of trees

Trees	Nitrogen fixing	Fruit	Fodder	Wood	Total
Leucaena	5	0	3	3	11
Albizia	5	0	4	4	13
Gliricidia	5	0	5	5	15
Mango	0	5	1	2	8

Questions to stimulate discussion

- What are the important criteria to consider? Are they all equally important?
- Do you agree with the final results of the scoring? Was there a lot of controversy about certain items?

Notes

- Instead of using paper or a blackboard, you can draw a matrix on the ground using a stick, and use stones, beans, leaves or twigs to show the items and the scores. Five stones means "best", and so on. Count up the number of stones to find out the total score for each item.
- If there are too many items to compare, there will be too many rows in the table, and the exercise will take too long. So choose only the most important ones to include in the table.
- If there are too many criteria to judge the items against, there will be too many rows in the table, and the exercise will also take a long time. Ask the group to choose the most important ones. The criteria should be of roughly equal importance (so a 5 in one column carries the same weight as a 5 in another column).
- Make sure that the criteria are all worded in the same way, all positive (e.g., produces a lot of fruit; controls erosion well). That will make the scoring easier.
- Avoid individual voting. Aim to generate discussion and agreement among the group, and to understand the reasons for the preferences.

Module 4. Knowing your soil

For farmers to make informed decisions on how to manage their soils, they need to understand their soils. This module will help the farmer field school participants learn about their soils. It covers how farmers identify different types of soil using their own knowledge, how the soil works, how it is formed, and its characteristics.

Learning objectives

After studying this module, you should be able to:

Identify different soil types using local indicators.

Determine soil characteristics and use them to check on the soil quality.

4

Farmers' knowledge of soils

Farmers know a lot about the soils in their villages and how they have changed. Farmers normally know how the land has been managed, and can remember what has happened in the past that might have affected the soils. They can easily distinguish different types of soils, and give names to each type. They know the problems and potentials of each type of soil, and they know what soil is best for cropping, grazing, woodlots, settlements and other uses. You should try to find out about past management practices (cultivation, burning, tree felling, etc.), natural processes such as erosion and flooding, and differences in how crops grow. This information will help you:

- Explain the current soil fertility and how it varies from place to place, and identify things the farmers may not know.
- Assess the soil properties and health, and guide the choice of management practices for particular farms, communities or catchments.

What is soil?

Soil is the upper part of the earth. It is living, and it supports life. Crops and trees grow in it, and it supports the natural vegetation. It is an important resource. It must be managed well to produce healthy crops and good yields, and to support people's livelihoods.

What makes up soil?

Soil is made up of solid rock particles and organic matter, water, air and living organisms. A good soil is made up of about 50% solids, 25% water and 25% air. The solid part is like a skeleton providing a structure for plant growth and a source of plant food or nutrients. Roots can absorb nutrients that are dissolved in water, use them to grow and produce seeds. The plant roots, and most living organisms in the soil, also need air in the soil to breathe. Soil organisms play an important role. They break down organic materials on the soil surface (leaves, etc.) and in the soil (dead roots and organisms etc.) to release plant nutrients. In this way, in a healthy, well-aired and moist soil, they can recycle soil nutrients and maintain the plant food supply.

People can change the soil composition by the way they manage the soil. They can make soil particles looser or more compact. That makes it easier or harder for plant roots to reach water, air and nutrients. A healthy soil provides enough water, air and nutrients to the plants while they are growing, and sustains life in the soil (the organisms that maintain soil quality). Good management is needed to maintain such a healthy soil.

Box 4.1. Soil words

Erosion. The removal of topsoil by water or the wind.

Food web. The interrelationships between the animals, plants and other living organisms.

Hardpan. Hard, compact layer in the soil.

Humus. Dark, well-decomposed organic matter in the top layers of soil.

Infiltration. The ability of water to soak into the soil.

Leaching. The washing of nutrients by water down through the soil.

Micro-organisms. Bacteria and fungi: living things that are too small to be seen.

Nutrients. Substances that plants need to grow healthily and produce seeds. The main nutrients are nitrogen, phosphorus and potassium.

Organic matter. Material in the soil made from rotting animals and plants.

Parent material. The rocks or sediments from which the soil is formed.

Permeability. The ability of water to pass through the soil.

pH. A measure of soil acidity. A low pH (less than 7) is acidic (like vinegar). A high pH (more than 7) is alkaline (like caustic soda or agricultural lime). A pH of 7 is neutral.

Plough pan. Hardpan caused by repeated ploughing.

Porosity. The amount of space or pores between the soil particles.

Rhizobia. A type of bacteria that live in the nodules on legume roots and fix nitrogen in the soil.

Rooting depth. The depth in the soil that roots can reach.

Salinity. Saltiness.

Soil acidity. The amount of acid in the soil. An acid

Soil organisms. Living things in the soil: bacteria, fungi, ants, earthworms, beetles and other animals.

Soil profile. The cross-section of the soil; a vertical cut through all the layers in the soil.

Soil structure. The arrangement of particles and lumps in the soil.

Soil texture. The size of particles in the soil.

Water holding ability. The ability of the soil to hold onto water.

Waterlogging. Where water fills up all the pore spaces in the soil.

Functions of soil

In addition to producing healthy plants, a good soil produces clean water and sustains trees and forests, productive rangelands, diverse wildlife, and beautiful vegetated landscapes.

- The soil controls how much rainwater flows over the land, how much seeps into the soil and is stored there, how much sinks through the soil into the deeper groundwater (to replenish wells and boreholes) and how much and how quickly water reaches the rivers and streams.
- It supplies water, air and nutrients to plant roots.
- It anchors plant roots.
- It stores nutrients which can be taken up by plant roots. The plants grow, and animals eat them. The plants and animals die, releasing the nutrients back into the soil. This cycle is repeated over and over.
- It breaks down harmful materials. Tiny living organisms in the soil (micro-organisms) can break down and make pollutants and wastes less harmful.
- It sustains different types of plant and animal life.
- It supports buildings, dams and roads. For many people, it is also the place to bury the dead.

Soil formation

Soils take a long time to form: thousands or millions of years. Soils are formed from weathered or broken rock and organic materials from plants and animals. These ingredients are mixed by living organisms and by movement of materials and water. They gradually gather into layers. The depth of soil from the soil surface down to the bedrock is the "soil profile" (► *Figure 4.2*).

Box 4.2. Examples of natural and human-led processes of soil formation

Natural processes

- Water moves soil particles and nutrients downhill
- Water can enrich or deplete the soil fertility
- Wind erodes the soil and deposits dust
- Clays move within soil
- Deep roots bring up nutrients
- Rhizobia (on legume roots) and other species fix nitrogen (an important plant food)
- Mycorrhiza accumulate phosphorus (another important plant food)

Human-led processes

- People take yield home and to other places
- People carry manure and wastes to the field
- People burn vegetation and residues
- People bring in mineral and organic fertilizers
- People plant woodlots and manage forests

Nature and people both influence how soil is formed. Understanding these influences can help farmers choose the best management practices for that soil. Soil builds relatively quickly in certain places (at the foot of slopes and in valley bottoms), and more slowly elsewhere (on slopes and on the tops of hills). Some layers in the soil build up faster than others.

Why learn about a soil profile?

The nature of the soil profile affects the use and management of each piece of land.

- If there is a hardpan or if the soil is shallow, crops may grow poorly: their roots cannot grow down, and there is little water and few nutrients in the soil. If the hard pan is shallow, the farmer may decide to plough deep, or to use a subsoiler to break up the hard layer.
- A deep soil is generally better for agriculture. It can usually hold more moisture and nutrients.

What affects soil formation?

Five main things influence the formation of soil:

- **Climate**, especially temperature and rainfall
- **Relief**: hills, valleys, slopes, flat land
- **Parent material**: the rocks or sediments from which the soil is formed
- **Living organisms**: microbes, plants and animals
- **Time**: how long the soil has been forming.

Figure 4.1. Climate is an important influence on the type of soil

Climate

At high altitudes, alternating cold and heat can break up rocks quite quickly. But biological processes are slow in cold places, so organic materials and minerals break down slowly.

Hot, wet climates mean that soil life thrives and many plants and animals can grow. They produce lots of organic matter – but this also breaks down quickly.

Relief

Hills and valleys mean that some places have more or less moisture, or are more exposed or protected than others. Steep slopes have shallow soils because of erosion. On flatter ground, sediments may accumulate, building up deep soils.

In lowlands where drainage is poor, the soil may form slowly but have a lot of organic matter because it decomposes only slowly.

Parent material

Most soils are formed from rocks (parent material) that have been gradually broken into smaller and smaller pieces. The type of rocks influences the soil that is formed: sandstone will produce a sandy soil, for example.

A few soils (such as peat) are formed in marshes from rotting plants, which gradually build up to make a thick layer.

Living organisms

Plant leaves protect the soil from the rain. Their roots bind the soil and prevent erosion, and draw nutrients from deep below the surface. When they die, plants add organic matter to the soil and leave a network of passages in the soil that allow water and air to penetrate.

Animals such as rabbits, moles, earthworms and beetles make burrows and mix the soil. Earthworms, along with micro-organisms and fungi that are too small to be seen with the naked eye, help organic matter decompose, carry nutrients around, and transform nutrients into a form that plants can use.

Larger animals affect the soil too. They trample the surface, graze the plants, and cause erosion. Humans plough and dig, herd animals, plant crops and cut trees. How people use the land can have a big effect on the soil.

Time

Soil formation is a slow, gradual process. So the length of time a soil has been forming affects its nature. Soils in river floodplains are often fairly new, so they have had no time to evolve. Older soils that have been forming for a long time are generally deep and have thick layers. Many of their plant nutrients have been washed away over the years, so they can be infertile.

► *Exercise 4.1 Soil walk*

► *Exercise 4.2 Describing a soil sample*

Indicators of soil quality

How can we tell whether a soil is healthy, can be used for certain crops, or are easy to manage? Here are some things to look for.

Soil layers

Topsoil. This is the topmost soil layer. It is usually dark. On flat land it is usually thick, while on slopes it is thinner. This layer is what farmers cultivate with a hoe or plough. It contains more organic matter than deeper layers, and supplies nutrients and water to roots. The deeper the topsoil, the more fertile is the soil, so farmers should manage it carefully.

In cultivated land, a thin, hard layer (a plough pan) may form below the topsoil. If farmers always plough to the same depth, this layer can get harder and harder, stopping roots from growing and water from seeping down. It will also make crops grow poorly and reduce yields.

Subsoil. This is a lighter colour than the topsoil and is more compact. It contains roots, earthworms, termites and different insects. If roots can grow down into the subsoil, they can tap the moisture and nutrients here. A deep subsoil can hold a lot of water. That means less water runs off the surface, and erosion is reduced. Some subsoils are clayey, so water cannot sink into them easily.

Weathered rock. This is usually hard and difficult to dig. It is made of broken rock and contains no organic matter. The soil particles are so close together that roots and water find it hard to pass through. Roots of big trees may reach this layer and draw water from it during the dry season.

Bedrock. This is the underlying rock beneath the soil. It is very hard. Water may collect above the bedrock, where trees and wells can reach it. In lowland soils, the soil may be very deep, so you cannot dig down far enough to reach the bedrock.

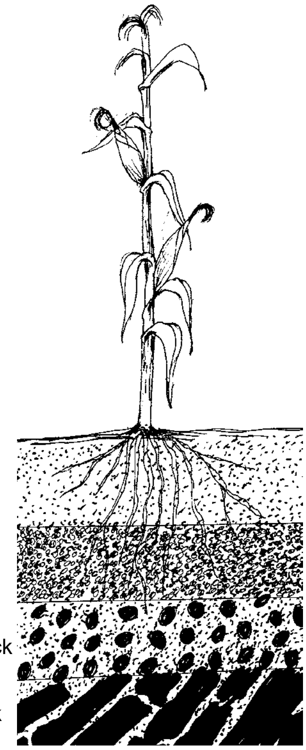


Figure 4.2. An example of a soil profile

Physical properties of soils

The soil's physical properties determine its appearance and feel. They include the colour, effective depth, structure, texture, compaction, water infiltration and water retention.

Colour. Farmers often use colour to distinguish different types of soil. They often say that a dark soil has a lot of organic matter. While this is often true, sometimes it is not. It is better to compare the topsoil to the subsoil: a dark topsoil has more organic matter (*Box 4.3*).

Effective soil depth. This is how far roots can reach downwards in the soil. Deep soils allow roots to grow downwards and sideways. That means the plant has a good chance of getting the water and nutrients it needs. In shallow soils, the roots cannot reach far, so the plant may suffer from shortage of water or nutrients.

Several things can limit the depth of the soil. A compact layer or plough pan may stop the roots from going deep. A stony layer or hard rock will do the same. So will an acidic layer in the soil. If the water table is high, roots cannot grow deeper because they need oxygen. Soils that are shallow or have a plough pan may suffer from drought because they cannot store much water.

Structure. Soil is made up of many, many grains or particles. Some are big (stones, gravel); others are smaller (sand, silt). They are bound together by clay and organic substances from decaying plant and animal materials, to

Box 4.3. What does the soil colour tell us?

Dark colours. Dark topsoil shows high organic matter content. High organic matter often means better drainage, good soil structure and nutrient levels.

Red-browns and oranges. 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 blue mottles. Some seasonal drainage problems (waterlogging) where air is lacking in the soil, especially in the wet season.

Grey. Poor drainage, too much water and not enough air.

Figure 4.3. Checking plant roots

make clods or aggregates. These shapes and sizes of the clods affect how water and air move in the soil (► *Figure 4.4*).

If the clods break down easily when raindrops hit them, loose particles can form a crust on the surface that prevents water from seeping in. On flat land, the water may lie on the ground. This is known as **waterlogging**. On a slope, the water runs off downhill, and as it concentrates it will carry soil particles with it. This is known as **erosion**.

Tillage, water management, and other farming practices can easily change or destroy the soil structure. Repeated hoeing or ploughing may break down the clods and reduce the amount of water that can seep in. It can form compacted layers, called hardpans or plough pans. Heavy tractors also compact the soil.

Compacted soils have few air spaces (pores) between the grains of soil. They can hold little water, so encourage runoff and erosion. If the soil is compact and hard, roots also find it difficult to penetrate (► *Figure 4.2*), so crops will not grow well.

► *Exercise 4.3 Assessing soil structure*

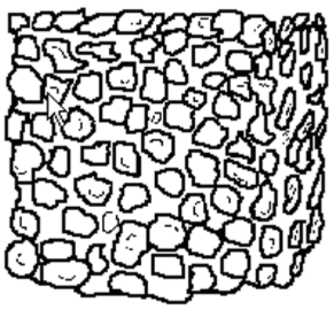
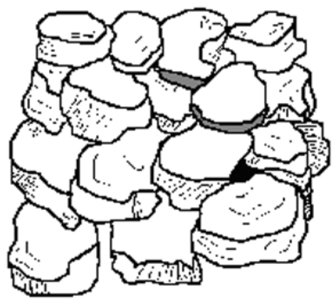
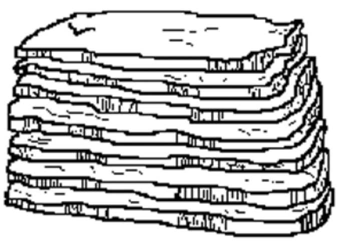
Granular	**Blocky**	**Prisms**
Like cookie crumbs. Crumbs are usually less than 0.5 cm across. Often found near the surface where roots have been growing.	Irregular blocks, usually 1.5–5.0 cm across.	Vertical columns of soil, several cm long. Usually found lower in the soil.
		
Columnar	**Platy**	**Single-grained**
Vertical columns with a salt “cap” at the top. Found in dry climates.	Thin, flat plates that lie horizontally. Usually found in compacted soil.	Soil is broken into individual particles that do not stick together. Loose consistency. Common in sandy soils.
		

Figure 4.4. Different types of soil structure

Soil texture. A soil's texture depends on the amount of sand (coarse particles), silt (medium) and clay (very fine particles) it contains. You can tell a soil's texture by rubbing it between your fingers and seeing what happens (► *Exercise 4.4 Determining soil texture*).

Texture influences many other characteristics of the soil. It affects the soil's structure, the amount of air or water it can hold, how many nutrients it holds, the movement of water, and the growth of roots. Sandy soils drain easily, and cannot hold water or nutrients for long. Loamy soils (with more silt and clay) can hold a lot of water and nutrients, so they are very good for growing crops. Clay soils hold more nutrients and water than sandy soils, but they do not allow water to move quickly, and they get waterlogged easily. A clayey soil is sticky when wet and hard when dry, making them hard to till.

Stones. Stones take up space and make it hard for roots to grow. They may stop roots from reaching water and nutrients, and they make tillage more difficult. Farmers can collect stones and make lines along the contour. These stone lines slow down water, help prevent erosion, and encourage water to seep into the soil.

Infiltration. This is the soaking of water into the soil through pore spaces, cracks and passages made by dead plant roots and living organisms. It depends on the number and size of pore spaces in the soil – the **porosity** – and the ability of water to flow through the soil – its **permeability**. Generally, more porous soils let more water infiltrate and percolate down to deeper layers. This is normally good because it reduces runoff and erosion and recharges the groundwater. But in porous sandy soils, a lot of water can wash or **leach** nutrients from organic materials and fertilizers down to deeper layers, where plant roots cannot reach them.

Some soils have compact layers with no or very few pores. These may be **plough pans** (caused by ploughing), layers of gravel, or hard surface layers. Such compact layers hinder water movement as well as root growth. If the soils have a surface crust, water will run off instead of seeping in.

► *Exercise 4.5 Measuring how fast water sinks into the soil*

Water holding ability. The amount of water that a soil can hold depends on how many pores (empty spaces) it has, how big the pores are, and the soil's texture. Sandy soils have large pores. They drain freely and hold less water than clays, which have smaller pores but remain moist longer as the tiny clay particles attract and hold tightly onto the water.

The movement of water into and through the soil, and the amount of water the soil can hold, affect many things: how much air there is for roots to use, how deep roots can penetrate, how hot or cold the soil gets, and how many living things can live in the soil.

► *Exercise 10.7 The ability of soils to hold water*

Chemical properties of soils

The soil's chemistry depends on the organic materials (made by plants and soil organisms) and inorganic materials (minerals) that make up the soil. The most important aspects of chemistry are acidity (measured as pH), organic matter and salinity.

Soil acidity or pH. Soils can be acid (like vinegar), neutral (like water), or alkaline (like lime). This is measured on a "pH scale" from 0 to 14. A pH value of 7 is neutral. A pH below 7 is acidic, while a pH of over 7 means the soil is alkaline. The pH of most agricultural soils is between 4.5 and 8.5. The pH affects the availability of plant nutrients and crop growth (► *Module 7*). It is easy to measure the soil acidity with a pH meter or with a simple test that uses a special paper and a chemical whose colour indicates the pH.

Some plants grow well on acid soils; other plants prefer alkaline soils. If the soil is too acid, farmers can apply lime. If farmers cannot get lime, or cannot afford it, adding mulch, litter or compost, or planting crops with deep roots can help reduce acidity.

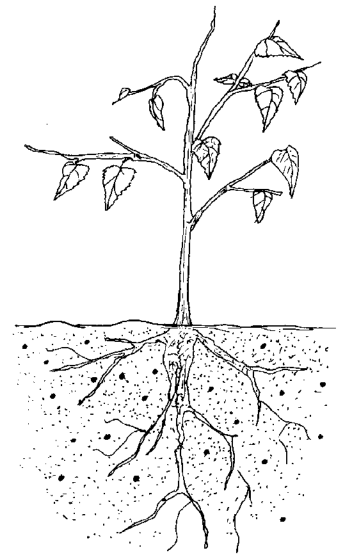
Organic matter is vital to maintain soil productivity, support soil life, keep clods together, and hold nutrients, water and air in the soil. For more on soil organic matter, ► *Module 5 Using organic materials*.

Salinity. In hot, dry areas, soils can become salty because water evaporates from the soil, leaving salts on the surface. Some soils are naturally saline. Irrigation can make soils salty if they are not drained well enough. Careful management is needed to wash the salts away from where roots can reach it. Most crops do not yield well on saline soils; a few, such as sorghum, can grow well there.

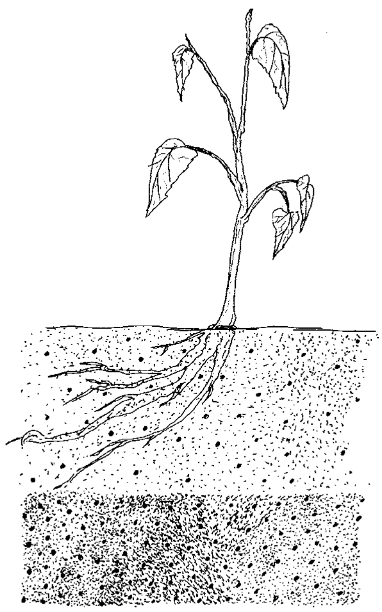
► *Exercise 5.1 Observing soil organic matter*

► *Exercise 5.2 Organic matter as glue*

► *Exercise 5.3 Decomposition of organic materials*



Normal, soil not compacted



Compacted soil

Figure 4.5. Effects of compaction on root growth

Biological properties of soils

Soil organisms. Earthworms, termites, ants, fungi and bacteria that live in the soils have a very big influence on it. They decompose organic matter. It may be easier to see earthworm casts and ant nests than the worms and ants themselves. There are also many **micro-organisms** – many types of bacteria and fungi that are too small to be seen, but farmers need to learn about them as they play important roles.

Rhizobia are helpful microbes that fix nitrogen in the soil. They live in small, round nodules on the roots of legumes such as clover and soybean. These small, pinkish nodules – the size of a pin head – can often be seen on legume roots. The pink colour shows that the *Rhizobia* bacteria are active.

Various things influence how active these soil living organisms are: temperature, moisture, air spaces, pH, organic matter and amount of nutrients in the soil.

For more on soil life, ► *Module 6 Encouraging soil life*.

Roots. Look at plant roots to see if the soil is compacted. If the roots are bent sideways, like the letter “L”, there is probably a hard layer in the soil. It is important to get rid of this hard layer, as it will limit the benefits of other practices such as adding fertilizers or organic matter.

Learn about the depth of different plant roots to plan what crops to grow where. Shallow-rooting crops can grow in shallow soils, while deep-rooting crops need deep soils to perform well.

► *Exercise 6.8 Becoming a root doctor*

Exercise 4.1 Soil walk

This exercise helps farmers explore the soil types in their area. It looks especially at how soil and water might limit crop productivity.

Do this exercise during participatory identification of opportunities for soil productivity improvement (▶ *Module 2 Improving land management*) with farmer field school participants. The facilitator should be familiar with exercises on describing a soil sample (▶ *Exercise 4.2*), determining the effective soil depth (▶ *Exercise 6.8*), soil structure (▶ *Exercise 4.3*) and soil texture (▶ *Exercise 4.4*), which are part of the walk.

Learning objectives

Identify soil types and the ways that farmers distinguish them.

Observe and determine soil characteristics.

Discover the effects of these characteristics.

Understand how the farmers' method of identifying soils is related to the soil characteristics.

Timing

Before the farmer field school has started, during the dry season – or even better, in the preceding wet season.

Preparation

Visit the area first, check it out and decide where the walk should go.

Duration

3–4 hours.

Materials

Hand hoe, panga or knife, ruler, container with water.

4

Steps

1. Invite the participants to go for a walk through the village's lands. You can start on the high ground and walk down into the valley, or go to different places where you expect the soils to be different.
2. Ask the farmers to identify the soils, and to say what they look for to distinguish between soils – things like colour, texture and depth.
3. Ask them to say how they decide on a soil's quality. How do they know if the soil's quality is improving, staying the same, or going down?
4. Discuss how the soil affects the way the land is used and the types of crops that are grown on it.
5. Each time the group is walking across a different soil type, stop and dig a pit near some crops or other plants. Dig down to 0.5 m deep if you can. Look at the layers in the soil, their colour, hardness, and so on.
6. In the pit, check how roots grow through the different layers. How many roots are there? How big are they? How far do they reach down?
7. Cut out a block of soil from each of the layers, weighing about 1 kg (you can hold it in one hand). Look at the pores, cracks and channels made by roots or earthworms. How big are they? How many are there? Keep this

Table 4.1. Recording form for soil walk

	Location 1	Location 2	Location 3	Location 4
Location (e.g., on slope, in valley bottom)				
Type of soil				
Farmers' criteria for judging soils				
Use of soil				
Constraints				
Management practices				
Effective soil depth (cm)				
Root abundance, size				
Soil pores				
Soil structure				
Soil texture				

block in one piece if you can. You can use it in ► *Exercise 4.2 Describing a soil sample*.

8. Check the soil structure (► *Exercise 4.3*). Look at the clods of earth. How big are they? How strong?
9. Check the soil texture (► *Exercise 4.4*).
10. Record all the findings on a form (► *Table 4.1*).
11. After the walk, discuss with the group what they have seen. See below for some questions to ask.

Questions to stimulate discussion

- How are the layers in a soil different? How do the various soils differ from one another?
- What problems could be associated with the soil characteristics you have seen?
- How can such problems affect the soil's productivity?
- What can be done to tackle these problems?

Exercise 4.2 Describing a soil sample

This exercise helps farmers recognize various soil characteristics and learn how they affect crops. It draws on what farmers already know about their soils.

Steps

1. Divide the participants into groups of 4 or 5 persons each. Give each group a soil sample collected the previous day.
2. Ask each group to discuss and describe the soil sample in their own words. Help them do this. Use the water to wet the soil so they can form it in their hands.
3. Ask each group to write their descriptions on a big sheet of paper or on cards.
4. One member of each group presents their description to the other groups.
5. Promote discussion of each presentation. Ask questions about the soil characteristics and plant growth.
6. Explain the main physical characteristics of the soil samples and how to observe and describe them.
7. Facilitate a discussion to compare the farmers' descriptions with a more scientific description.
8. Summarize the main points discussed during the exercise.

Learning objectives

Examine the topsoil and subsoil from the participants' own farms.

Identify and describe the main characteristics of the soil.

Describe the main physical characteristics of the soil.

Relate these characteristics to the growth of crops.

Timing

Before the farmer field school has started, during the dry season – or even better, in the preceding wet season. If the soil is very dry and hard, it is difficult to take soil samples. You can do this exercise the day after the soil walk (► *Exercise 4.1*).

Preparation

During the soil walk the day before, collect samples of topsoil and subsoil from different places.

Duration

1 to 2 hours.

Materials

2 or 3 samples (1 kg each) of different soils taken from soil pits; glasses of water, large sheets of paper, marker pens (or cards and pencils).

Adapted from

FARM (1998)

Exercise 4.3 Assessing soil structure

This exercise helps farmers examine different kinds of soils and to discuss the soil structure.

Learning objectives

Recognize and classify the soil structure.

Learn what different soil structures mean for managing the soil and crops.

Timing

In the wet season before the farmer field school has started, or during the dry season (but when the soil is moist). If the soil is very dry and hard, it is difficult to take soil samples.

Preparation

–

Duration

1.5 hours.

Materials

Shovels, notepaper, pencils.

Adapted from

FARMESA (2003)

Steps

1. Go to a field and dig up a square block of soil, about two hands wide. Try not to disturb or break the block.
2. Examine the structure of the block. Break off pieces and look at their shape and structure. Are the particles loose, or are they bound hard to each other. Look for channels and cracks where water and air can pass through.
3. When the participants know what to do, divide them into groups of 4–5 and ask each group to go to a different place (forest, grazing land, garden, etc.) and do the same thing.
4. Meet again as a full group and discuss what you have seen. What do the different structures mean for how to manage the soils and crops?

Questions to stimulate discussion

- What differences and similarities in soil structure did you see in the different places?
- In which places will roots grow easily? How will the roots differ from place to place?
- How does the soil structure affect how much water seeps into the soil, and how long it stays there?

Exercise 4.4 Determining soil texture

This exercise enables farmers to judge whether a soil is clayey, silty, sandy or some combination of these (e.g., a loam).

Steps

1. Take about a spoonful from the soil sample in your hand.
2. Add a little water to the soil, one drop at a time. Use your hands to work the soil until it is sticky, then form it into a various shapes (► *Figure 4.5*). That tells you its texture.

Learning objectives

Evaluate soil texture in different soil types.

Timing

In the wet season before the farmer field school has started, or during the dry season (but when the soil is moist). If the soil is very dry and hard, it is difficult to take soil samples.

Preparation

–

Duration

40 minutes.

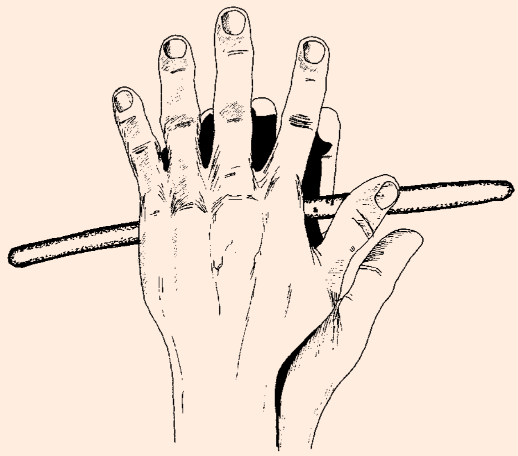
Materials

Water dispenser or cup, soil sample, tablespoon, water.

Adapted from

Barrios et al. (2000)

4



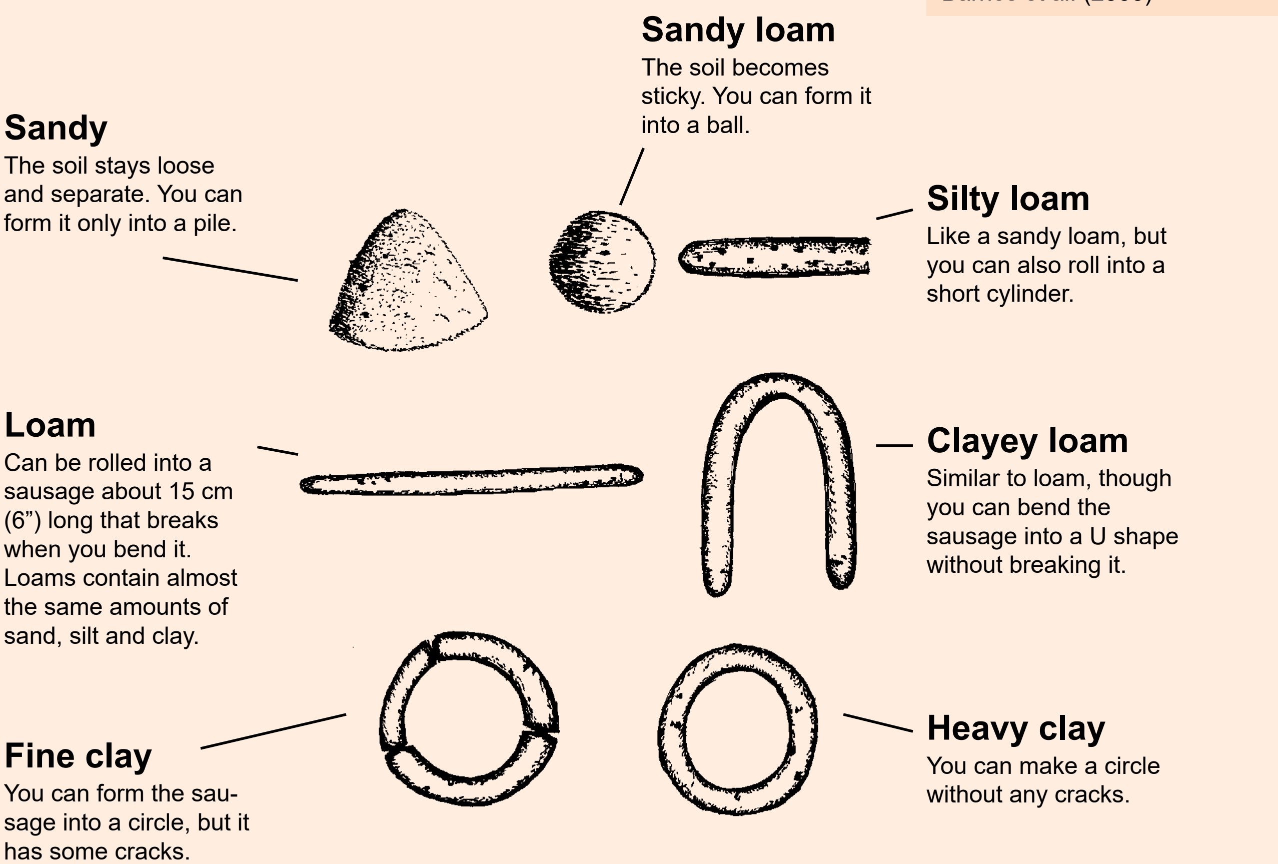


Figure 4.6. See if you can form the soil into these shapes

Source: Agricultural compendium for rural development in the tropics and subtropics.

Exercise 4.5 Measuring how fast water sinks into the soil

Learning objectives

Measure how quickly rainwater sinks into different soils.

Observe the differences on the surface and below before and after rain.

Understand what affects how quickly water sinks in.

Timing

After discussing the effects of animals and plants on the soil.

Preparation

Cut the top and bottom from a large can. Make several such cans if you want to do the experiment in several places at once.

Duration

1.5 hours.

Materials

Large can, 15–20 cm across and about 20 cm deep, with the top and bottom removed; piece of sacking, 10-litre bucket of water, emulsion paint, watch, hammer or large stone, notepaper, pencils.

Adapted from

Barrios et al. (2000)

Rainwater sinks into the soil through cracks and through channels left by animals and plant roots. In this exercise, farmers compare how quickly water sinks into cultivated and non-cultivated soils.

Steps

1. Find two or three places to do the experiment – e.g., a ploughed field, a no-till field, very clayey vs. sandy soil. If you choose a slope, make sure the infiltration ring can stand level.
2. At each site, push the can about 10 cm into the ground. If the soil is hard, use the hammer, but try to disturb the soil along the sides of the ring as little as possible. Put the sacking over the ring (this prevents the water from disturbing the surface when you pour it into the can).
3. Mix a little paint into the water to colour it. (The paint is to make the water easy to see when you dig out the soil later in the exercise. If you have no paint, you can do the exercise anyway, but the water may be hard to see.)
4. Make a note of the starting time. Pour 10 litres of the paint-coloured water into the can.
5. When the water has sunk into the soil completely, make a note of how long it has taken.
6. Remove the can, then dig a pit across half the circle where it was. Look at how far the water has sunk in, and how it has moved down channels and cracks in the soil. Check the soil texture at the surface and in the different layers beneath.
7. Repeat the exercise at the other places.
8. Compare the results. Why did the water sink in quickly in one place and slowly in another?
9. Discuss how this affects the management of the soils and the crops grown there.

Questions to stimulate discussion

- In which soil did the water sink in fastest?
- Why? What affects how quickly it sinks in?
- How might changing the management practices change the speed?
- What will happen if the water does not seep in quickly? How might this affect the crops, the farmers, the community and the environment?
- How might the speed affect runoff, soil erosion and drainage?

Figure 4.7. Measuring how fast water sinks into the soil

Module 5. Using organic materials

It is important to manage organic materials properly to make the farm productive today and tomorrow. This module helps farmers understand organic materials, how plants decompose, how to manage organic materials well and how to increase the amount of organic matter in the soil.

This module is closely related to the modules on crop nutrient management (▶ *Module 7*), reduced tillage, increased soil cover and crop rotations (▶ *Module 8 Conservation agriculture*), livestock management (▶ *Module 9*) and farm biodiversity (▶ *Module 14*).

Learning objectives

After studying this module, you should be able to:

Understand how to manage organic materials to increase and sustain farm productivity.

Understand how organic materials decompose.

Decide how to manage organic materials on the farm.

5

Humus

Organic materials such as dead plants and animal wastes provide food for living organisms: earthworms, termites and other animals, fungi and bacteria. These break down, or **decompose**, the organic materials and release the nutrients they contain, and make the dark organic matter (**humus**) that we can see in the top layers of the soil. You may be able to see the remains of leaves, fibre and wood in the humus.

To some extent, the amount of humus in the soil depends on the soil type and the past land use. Soils that evolved under a forest or in a swamp will contain a lot of organic matter. But the amount will decrease rapidly if the land is cleared and cultivated. Soils in hot, dry areas will have less humus because few plants grow there and organic materials decompose quickly. Clays hold humus more tightly than sandy soils, so have more of it. Burning the vegetation reduces the amount of organic materials. Harvesting crops and removing the stalks also takes organic materials away from the land. Farmers have to return organic materials, or the soil will eventually become unproductive.

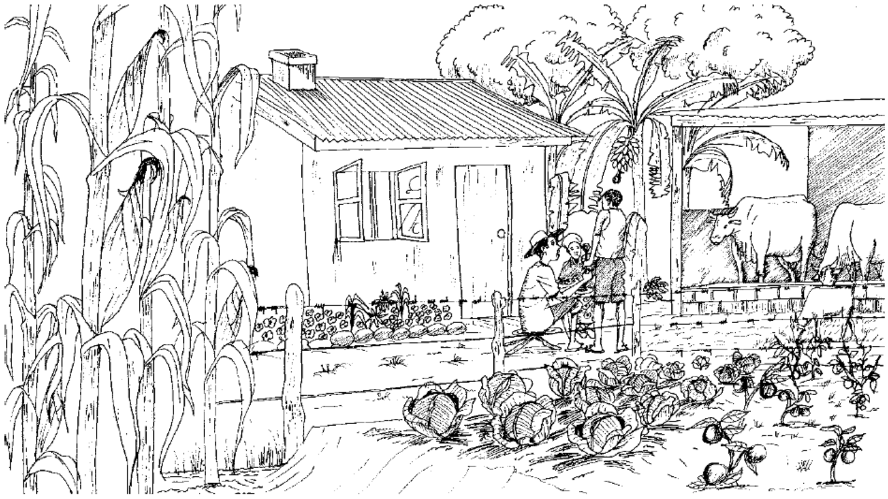
Why is humus so valuable?

Farmers sometimes call humus "**soil strength**". It affects the soil in many ways.

- Soils that have a lot of humus are dark. There is more humus in the top layers of the soil, which is why the topsoil is usually darker than the subsoil.
- Humus acts like glue, binding soil particles together. That is what gives fertile soils their crumb-like structure. This lets water sink into the soil, allows roots to penetrate and makes the soil resist erosion.
- Humus holds water and nutrients so plants can use them.
- Humus has many nutrients that plants use. It has many trace elements that artificial fertilizers do not have (▶ *Module 7*).
- It acts as a home and as food for many forms of soil life, which in turn are important for a healthy soil.

If the farmer understands the importance of humus, he or she can make good decisions on how to manage the soil. That will lead to good crops and productive livestock.

Figure 5.1. A farm has many sources of organic matter



Organic materials

Humus comes from dead plants and animals, and from "wastes". These "organic materials" include:

- **Crop residues** above and below ground: straw, stalks, husks and roots.
- **Other plant materials**: leaves, stems, weeds, tree prunings.
- **Green manure and cover crops.** Farmers grow these to protect the soil and provide organic material.
- **Wild plants**, including weeds, along the edges of fields, in hedges and by the roadside.
- **Waste from farms and industry**, such as coffee pulp, sugarcane bagasse, and husks from rice mills.
- **Animal by-products**: dung, feathers and even bones.
- **Household waste**: vegetable peelings and human waste.

All these materials can be used to restore and improve the soil fertility and health. They can also protect the soil from the sun, heavy rain and erosion. They can be applied on, or in, the soil in many ways.

How do organic materials change into humus?

Earthworms and other animals are like engineers. They dig and burrow, build and carry. They pull organic materials into the soil. They mix dead roots and other materials. Millions of tiny living organisms – most too small to see – break down (decompose) organic materials and release energy and nutrients. Some types of animals eat other types, in a complex **food web** in the soil (► *Module 14 Managing biodiversity*).

When plant or animal materials decompose:

- Part is transformed into humus.
- Part decomposes completely to make carbon, nitrogen and other nutrients that plants can use as food.

Managing organic matter and managing the family's food

Managing organic matter in the soil is like managing food for your family. You need to make sure there is enough food, and the right type of food, to keep everyone well fed and healthy.

- Plants and living organisms need a continuous supply of food. – *The family will be healthier if they have one good meal, with different types of food, every day throughout the year. That is better than a few big feasts after the harvest, then going hungry.*
- Plants need more nutrients at certain stages of their growth. Giving nutrients at the wrong time may mean that plants cannot use them. – *Growing teenagers need more food than the old or young.*
- When plants are young, their roots are not well developed. Sandy soils and soils with poor structure make it hard for plants to get nutrients. In such cases, nutrients need to be supplied little and often. – *Babies need small quantities of food at regular intervals.*

5

Quality and nutrient content of organic materials

Organic materials may contain different amounts of nutrients. They may decompose and release nutrients quickly or slowly.

- **Soft, green plants**, animal dung and coffee husks generally contain a lot of nitrogen. They decompose quickly. They form little humus but are useful, quick sources of nutrients for plants. These are high-quality fertilizers.
- **Hard, brownish materials** are woody or fibrous. They need more time to decompose, but they form more humus. They help maintain the structure and good properties of the soil. Examples: straw, twigs, maize stalks, dead roots.
- **Soft, brown materials** (such as dry grasses, leaves and dead weeds) or **hard, green materials** (such as tree leaves, banana and mango leaves) provide moderate nutrients and fibre (► *Table 7.4*).

The time materials need to decompose also depends on the soil humidity and temperature. If the soil is warm and moist, earthworms, bacteria and other living organisms are very active. Organic materials decompose faster there than in cooler or drier climates or at high altitudes.

In semi-arid areas, organic materials decompose fastest at the start of the rains because it is warm and wet, and a lot of organic material has built up during the dry season. That releases a flush of nutrients, ready for uptake by the new crop. If the organic matter is not protected somehow, the nutrients may be washed away by the rains.

Holding and supplying nutrients

Humus can hold onto or absorb nutrients. It acts like a magnet for nutrients that are released when organic materials decompose, or that farmers add as fertilizer. The humus then gradually gives these nutrients up again to plant roots and microbes.

Box 5.1. Organic matter is like a caring mother

Imagine throwing a bag of peanuts over a child sitting on a chair. The child will catch some of the peanuts and will eat them. But most of the peanuts will fall on the ground, where the child cannot reach.

The same happens with chemical fertilizers applied to a crop. The crop uses some of the nutrients, but most will be washed away by rain.

Organic matter is like a caring mother who holds the peanuts in her pockets. She gives a few each day to the child when it is hungry. In the same way, organic matter catches nutrients and releases them slowly when the plants need them.

Soil without organic matter has no food store. It needs a mother to provide its food. (Adapted from IFOAM, 2002)

But if there is not enough humus, the nutrients are lost easily. They may be dissolved by water and washed downwards in the soil (this is called "leaching"). Or they may turn into gas and escape into the air. One of the most important plant nutrients, nitrogen, is lost this way.

If it is too cold or dry, or if there is too little organic matter, earthworms and microbes cannot thrive, so nutrients will be released only slowly. Just as people need food, air, water and warmth, so does soil life.

The soil type also affects the availability of nutrients (► *Module 7*):

- Many soils in the tropics are **poor**, especially in drier areas. They have been exposed to the sun and rain for many years. There is not enough vegetation cover to let organic matter build up. Generations of people have grown crops on these soils, taking nutrients out without putting any organic matter back. They have burned vegetation instead of adding it to the soil. Ploughing has created a hard layer below the surface. Animals trample the soil and make it hard.
- Many soils in the tropics are **acidic**. This means that they do not release many nutrients to the plants. For such soils, organic matter added by farmers is the source of almost all nutrients for the plants. In contrast, clayey soils in valley bottoms are wetter and have more vegetation cover. The clay particles interact with organic matter and hold nutrients and other elements. Such soils are less acidic and can provide more nutrients to plants.

Microbes need to eat too. If there is little organic matter in the soil, the microbes will take most of it for themselves, leaving little for the plants. Farmers may have seen this if they apply low-quality compost or manure. The plants often go yellow because of the lack of nutrients. Later they may turn

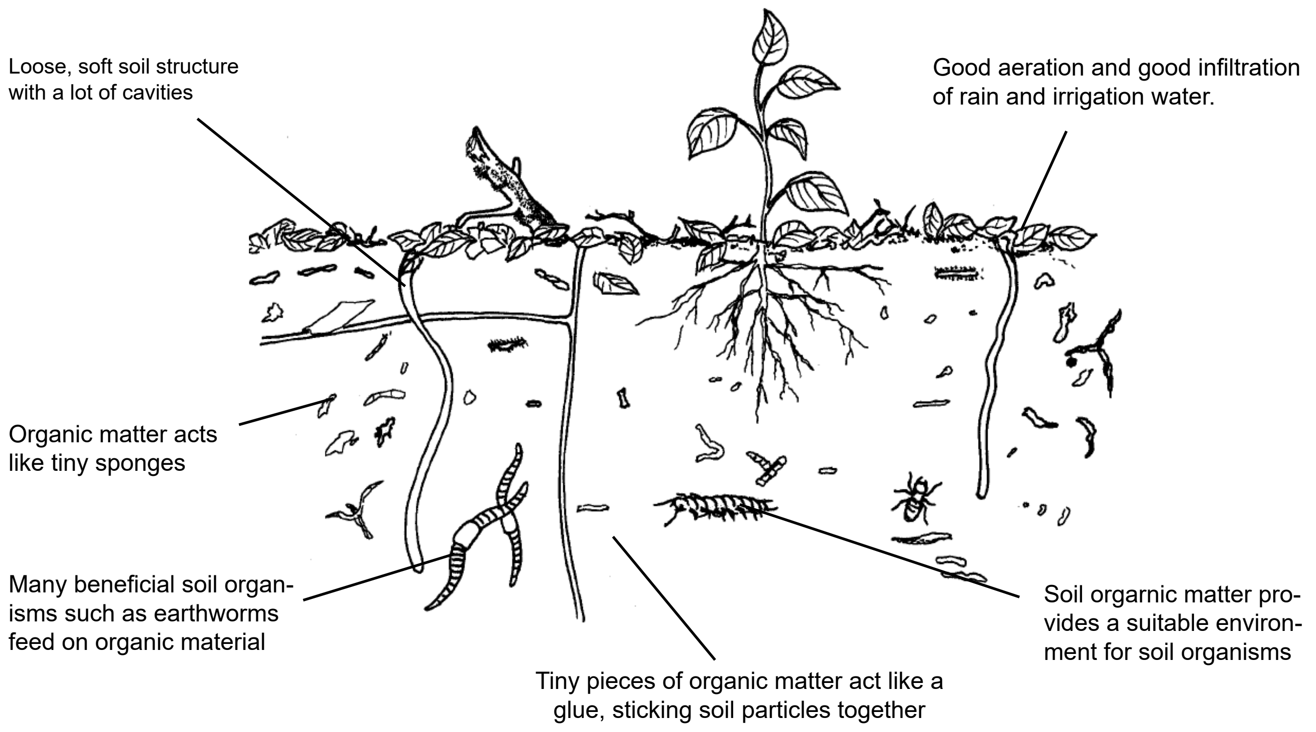
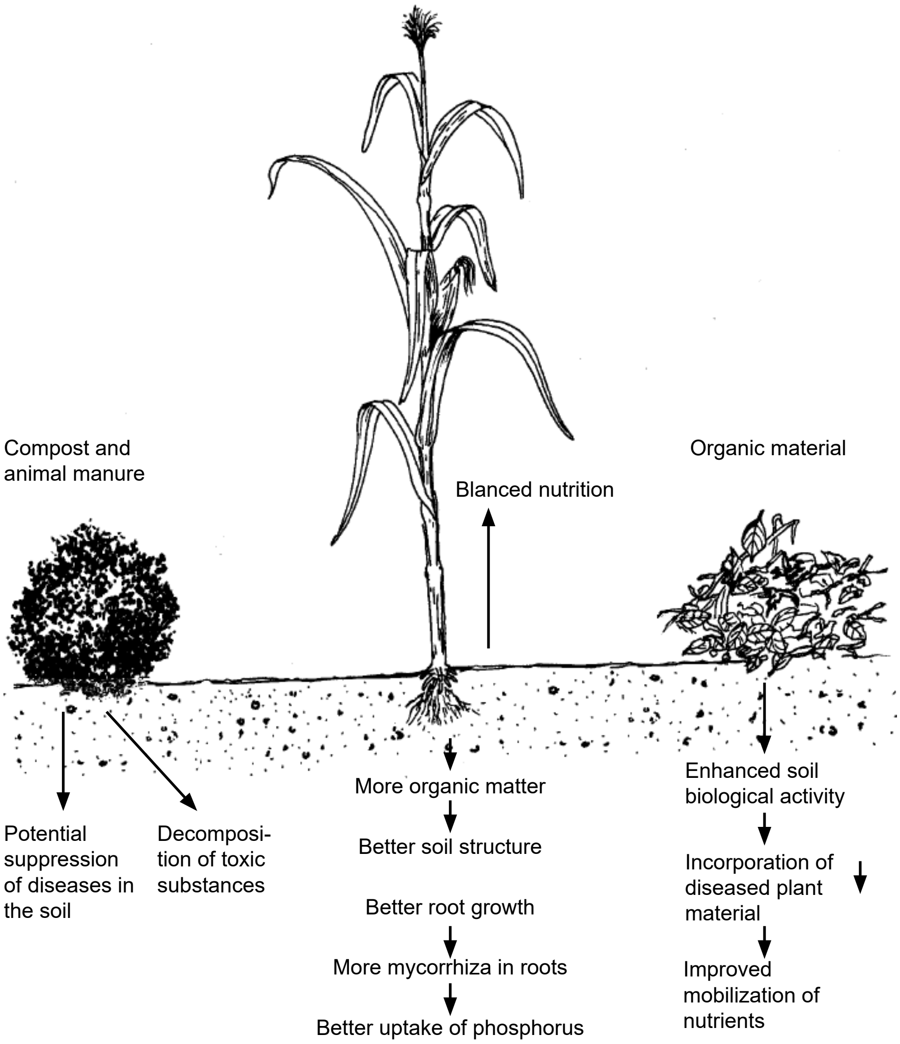


Figure 5.2. What organic matter does for the soil. Adapted from IFOAM (2002)



Adapted from IFOAM, 2002

Figure 5.3. How organic materials and biological activity make plants healthy

a healthy green again after the microbes have decomposed the compost further and released the nitrogen it contains.

This shows how important it is to apply the right type of organic materials at the right time. For example:

- Apply **low-quality** (fibrous, woody) materials well before the crops need the nutrients. That gives time for them to decompose, and gives the crops a steady supply of food.
- Apply **high-quality** (soft, green, leafy) materials for young crops with shallow roots. The leaves will rot quickly and give the young plants food. On acid soils, apply leafy material frequently to maintain a steady supply of plant food.

Holding water

Humus holds water and makes it available to plants. This is very important in dry areas, or where rainfall is unreliable. Humus is like a sponge. When it rains, it absorbs lots of water and holds it. A soil rich in organic matter will hold moisture for more time after the rain, compared to a poor soil.

► *Exercise 5.1 Observing soil organic matter*

Box 5.2. Soil is like a sponge

If you dip a sponge in water then take it out, it will drip for a while, and then stop. But it is still wet. If you squeeze it, a lot more water will come out. After a while it will still be moist, no more water will come out when you squeeze it, but it still feels wet.

The same is true for water held in the soil. After rain, some of the water is readily available. As the soil gets drier, plants have to work harder to get the water out.

More organic matter is like a bigger sponge. It holds more water, and keeps a ready supply for longer.

► *Exercise 10.7 The ability of soils to hold water*

► *Exercise 10.5 How the soil holds water*

► *Exercise 5.2 Organic matter as glue*

► *Exercise 5.3 Decomposition of organic materials*

► *Exercise 10.5 How the soil holds water*

► *Exercise 10.7 The ability of soils to hold water*

Increasing the organic matter in the soil

Some ways to increase the amount of organic matter in a farmer's soil:

- **Leave crop residues on the field** instead of burning them or taking them away.
- **Make compost.** Compost is good because it is already decomposed and can supply nutrients to the plants.
- **Apply animal manure.** Dung is rich in nitrogen. It provides soil organisms with the energy to decompose organic matter. But it breaks down fast and does not stay in the soil for long.
- **Spread mulch on the soil.** Hard, woody materials break down slowly and stay in the soil a long time. Decomposing leaves provide nutrients to plants quickly. Mulch also protects the soil from the rain and sun, keeps the soil moist and at a steady temperature, prevents erosion, and suppresses weeds.
- **Incorporate organic materials into the soil.** Young, green plants decompose and release nutrients quickly. For example, tithonia rots in just 2 weeks, so gives a crop a quick dose of nitrogen. But young green plants make less long-lasting humus than do fibrous or woody materials.
- **Plant a cover crop.** Cover crops protect the soil and add to the organic matter, but they also use up water. Leguminous cover crops fix nitrogen in the soil so the following crop can use it.
- **Reduce tillage.** Ploughing or hoeing speeds up the decomposition of organic matter, because it brings air into the soil. Less ploughing, or not ploughing at all, slows this decomposition. Ploughing also damages and even kills living organisms, and makes the soil lose moisture through evaporation.
- **Rotate and mix crops.** Crop rotation and crop mixtures improve the organic matter content of the soil and may improve the soil structure if they are managed well. Different crops have different types of roots that pull nutrients from different soil depths. Legumes fix nitrogen from the air.
- **Agroforestry.** Prunings from trees and shrubs can be used as mulch or to make compost. Trees have deeper roots than most crops, so they absorb nutrients that annual crops cannot reach.

► *Exercise 5.4 Sources of organic material*

It is a good idea to increase the amount of organic matter in the soil. But how to produce it? There are two major problems:

- How to deal with livestock?
- How to control pests and diseases?

Figure 5.4. Tithonia rots quickly and is a good source of nitrogen

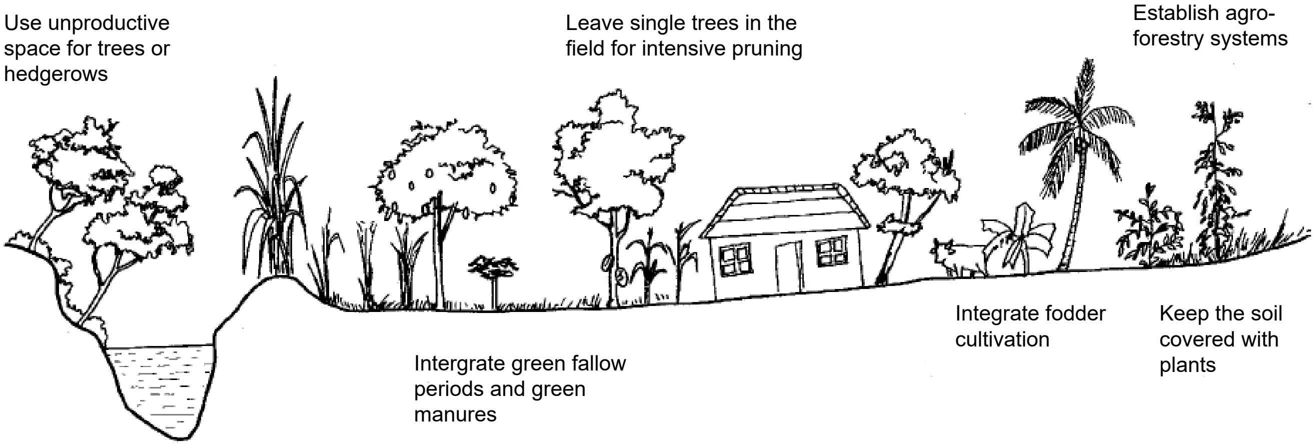


Figure 5.5. How to produce more biomass on the farm

Feed the soil, or feed your livestock?

Livestock need to eat, and fodder is often scarce. Should farmers feed their animals, or should they let the plants decompose and feed the soil? Can they do both? And how can they prevent other farmers' animals from eating all the plants they have left on their fields?

Most farmers would choose to feed their animals rather than leaving plants in the field to feed the soil. They may not realize that in the long run this will mean lower yields and less food for the animals. A well-fed soil produces bigger, healthier plants, and more for animals to eat.

The farmers might decide to use the leafy tops of maize or sorghum as feed, but leave the woody stalks on the ground as mulch.

It can be difficult to stop animals from grazing on a field after harvest. That requires discussion and agreement with other members of the community. Perhaps several farmers can negotiate with their neighbours to change the villagers' grazing practices. The livestock owners must also be able to benefit from the change, or they will not agree to it.

Animals eat crop residues and produce manure. That is easy to manage, but what happens to the manure? It may build up in the animals' night enclosure instead of on the fields. It is better to bring the manure back to the fields and spread it on the ground, or use it to make compost.

Stall-feeding animals is another option. The farmers can collect the dung and urine and bring it back to the fields, either fresh before sowing or as compost. It is a good idea to apply compost only where the crops can reach it – along planting lines or in planting pits.

► *Module 9 Managing livestock.*

Pests and diseases

Many farmers worry that leaving crop residues in the field will encourage pests and diseases and spread weeds. So they remove the organic matter from the fields or burn it. That means losing a lot of valuable organic matter.

Perhaps the farmer field school members can think of ways to use these organic materials but still control pests, diseases and weeds. For example, how about rotating crops, or applying herbicides? Residues provide homes for natural enemies of pests and diseases, so regulate the balance among the living organisms in the field. Always apply crop rotation or mixtures. Weeds do not germinate in the dark, so when the soil is covered, few weeds germi-

Figure 5.6. Plant materials are valuable. Farmers must decide how best to use them.

nate. If the soil is not worked, weed seeds deep in the soil are not brought up to the surface, so cannot germinate.

Termites like to eat dry, dead materials. But if they cannot get enough, they may attack the woody parts of crops. The farmer field school can discuss, observe and experiment on how to manage termites. What works best in their area and farming situation? Do termites have any benefits? Different methods may work with different crops and in different places.

► *Exercise 6.3 Living with termites*

► *Exercise 6.9. Maximizing soil cover to increase biological activity*

When, and how much, organic material to apply

Organic matter is continually decomposing in the soil. So the organic matter must be renewed every season.

The amount of organic matter to apply depends on four things:

- The availability of organic material.
- The amount of nutrients it contains (► *Module 7*) and how fast they are released.
- The amount of nutrients the crop needs. This affects the management of the organic material – e.g., should it be worked into the soil or used as mulch?
- The effects left over from the previous crop. For example, roots and stubble are a source of nutrients and organic materials.

How to conserve soil organic matter

Here are some ways of reducing the loss of organic materials:

- **Don't burn plant materials.** This is a big loss. The organic matter is destroyed, and most of the nitrogen goes up in smoke. Burning is like throwing away next years' profit!
- **Reduce or avoid tillage.** Ploughing and hoeing speeds up the decomposition of organic materials. It is like stirring the embers of a fire: it lets in more air and makes the fire burn faster. It destroys the soil structure that roots and animals living in the soil have worked hard to build up. Farmers till the soil mainly to control weeds and to prepare the seedbed. Instead, they can use zero-tillage, and control weeds with herbicides or cover crops. That conserves the soil structure, maintains soil life, conserves moisture and organic matter, and reduces the amount of work needed for land preparation and weeding.
- **Prevent erosion.** Keeping the soil covered for as much of the year as possible will reduce runoff and control erosion. If the soil is unprotected, heavy raindrops batter the surface, dislodging soil particles. These particles can easily be carried away by water, or blown away by the wind. This is the topsoil that is lost – the richest part of the soil that contains most of the organic matter and plant food. On gentle slopes, a good plant cover, mulching and good roots are enough to prevent erosion. On steep slopes, it may be necessary also to dig trenches to carry excess water away, make lines of stones and trees, plant along the contour, or make terraces.

"If you do not look after your animals, they get weak. If you do not look after your soil, it will get weak and it will not provide for you."

Managing organic materials

Farmyard manure

Animal dung and urine contain nutrients that are valuable for crops. The type of feed the animals eat determines the quality of the dung. Poor fodder produces fibrous (low-quality) dung with few nutrients.

Dung contains nitrogen. Plants can use a small part of this nitrogen directly, but the dung must decompose before they can use the rest.

Animal **urine** contains a lot of nitrogen – about the same amount as dung. Plants can use this nitrogen straight away. Urine also contains a lot of potassium, another important nutrient.

Farmers should store the manure properly to prevent the nutrients from escaping. They can put down straw or bedding on the stable floor or on the ground in the paddock. That will soak up the urine. Every few months, the farmer can collect this farmyard manure and use it as fertilizer.

Leaving the farmyard manure exposed to the sun and rain will allow a lot of nutrients to escape. ► *Module 9* describes how to collect and store it properly.

How much nitrogen in manure?

- On average, one cow weighing 250 kg produces around 1 ton of (dried) dung a year – about 20 bags holding 50 kg. A ton of dung contains 5–7 kg of nitrogen. That means a 50 kg bag of dung contains about 300 g of nitrogen.
- One goat or sheep weighing 25 kg produces about 120 kg of (dried) dung a year – around 2 bags. 120 kg goat or sheep dung contains 1–2 kg of nitrogen, so 1 bag has about 500 g of nitrogen.

► *Exercise 9.4 Different types of manure*

Liquid manure

Liquid manure can be made from farmyard manure or plant material. Making liquid manure is quicker than making compost. It is useful for growing vegetables or for parts of the field where the farmer wants to apply more fertilizer – for example if the crops need nutrients fast.

Fermented urine is good for vegetables, and it repels pests.

► *Exercise 5.5 Making liquid manure*

Compost

Composting turns fresh plants and waste materials into a long-lasting organic matter. Making compost takes quite a lot of work, so is best for small areas and valuable plants close to the home – such as bananas, fruit trees or vegetable gardens. Farmers can also put small amounts of compost in planting pits in the field.

Why use compost?

- Compost is a well-balanced fertilizer. It contains all the main plant nutrients, plus many trace elements.
- It is cheap to make (or free).

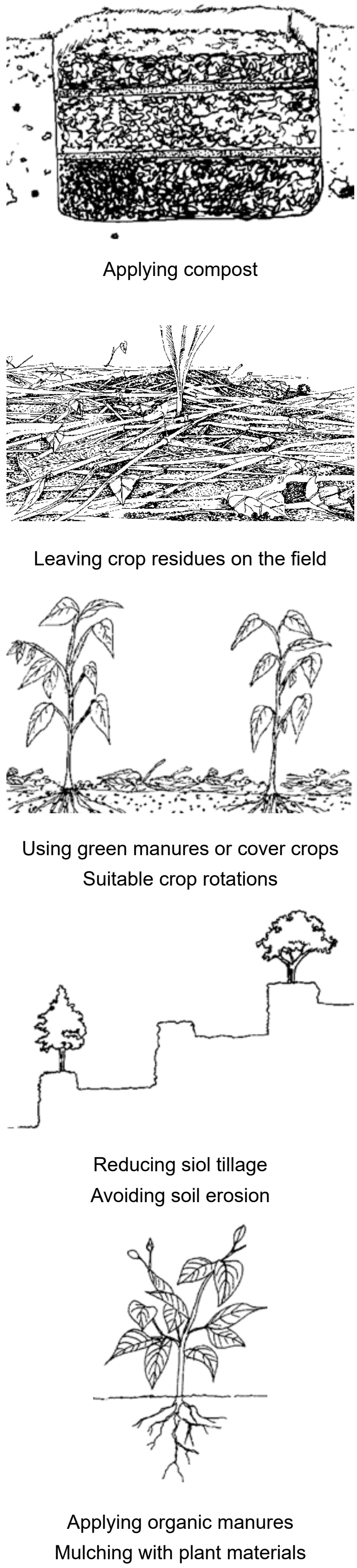


Figure 5.7. How to conserve soil organic matter

Adapted from IFOAM (2002)

During the dry season, animal manure can be stored in a pit to reduce the risk of it drying out. Dig a trench around the pit to prevent waterlogging if it rains.

The pit should be 70–80 cm deep with a slight slope at the bottom. Compress the bottom then cover it with straw.

Fill the pit with layers about 30–40 cm thick, compress each layer, and cover with a thin layer of earth. Fill the pit until it stands about 30 cm above ground and then cover it with 10 cm of soil.

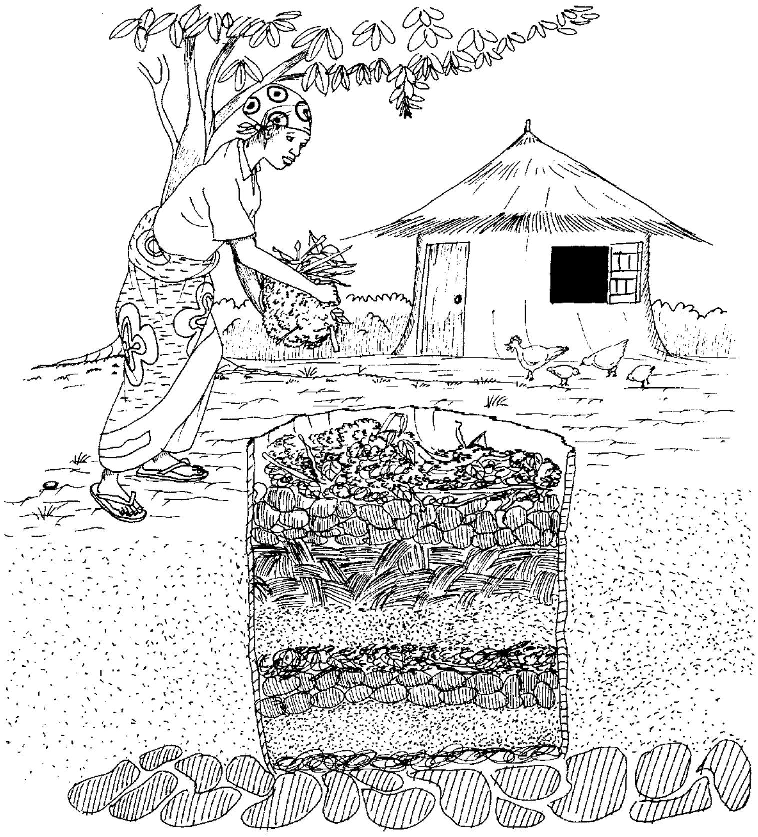


Figure 5.8. Storing manure in a pit.

- As plants decompose the compost heap gets warm. This heat kills weed seeds and germs that cause diseases.
- Compost suppresses soil-borne diseases.
- It makes acid soils less acidic (it raises their pH).
- It increases the amount of organic matter in the soil.
- It is a good way to use high-quality "waste" such as poultry manure, sheep and goat dung, weeds and household waste.

What to put in a compost heap?

What goes into the compost pile affects what comes out!

The quality of organic materials depends on how much nitrogen they contain. Materials with a lot of nitrogen decompose easily. Hard, fibrous materials have less nitrogen, so decompose slowly (► *Table 5.1*).

It is important to have different materials in the compost pile.

- Coarse materials allow air to get in and move around the pile.
- Manure and leafy materials decompose rapidly and provide lots of nitrogen.
- Fibrous materials break down slower but stay in the soil longer.
- Soil contains many living organisms.
- Ash contains phosphorus.
- A grass cover on top of the pile keeps the heat in.

Table 5.1. How fast does it decompose?

Type of material	Amount of nitrogen	Decomposition rate (wet season)
Hard and brown – maize and sorghum stover, twigs	Little	12+ weeks
Soft and brown – dead grass, soft straw		6–8 weeks
Hard and green – banana and mango leaves, tomato stems		4–6 weeks
Soft and green – cabbage leaves, green manure, weeds, tithonia	A lot	2–4 weeks

Making compost

Compost can be made in a pit or in a heap. A pit reduces evaporation and the need for watering, so is good in the dry season or in dry areas. But composting needs air, so the material in a pit has to be mixed frequently if the compost is needed quickly. Air gets into a heap more easily, so mixing is not needed. Otherwise, the process is the same.

If you have a lot of materials to compost at the same time, you can make compost in one go. The compost gets warm quickly, speeding up decomposition and killing weed seeds. Add the materials in layers: coarse materials, then a layer of fresh plants, then a layer of dung, then ash, and so on. That will let air get into the pile and speed the composting process.

If you do not have a lot of materials at the same time, you can make compost more gradually. Add materials to the heap or pit as you get them. The heap will not get as warm, so composting will be slower.

Composting may take up to 2 months. Keep the pile moist (the living organisms that do the work need to drink!). To test the moisture, make a hole with a stick in the pile and push a handful of hay into the middle of the pile. Take it out after 5 minutes. It should feel damp. If it is dry, sprinkle some water onto the pile.

Cover the heap with banana leaves or grass cuttings to reduce evaporation. If the pile gets too wet, open it up and mix in some dry material, or allow it to dry in the sun before rebuilding the pile.

Box 5.3. What to use in making compost

Suitable for composting

Nearly all plant materials

By-products, such as coconut husks, groundnut shells, rice husks or coffee berry residues

Dung from cattle, goats, sheep, pigs and poultry. (Pig and poultry manure is high in nitrogen, but smells!)

Feathers

Wood ash

Rock phosphate (it is better to put this in the compost heap than directly to the soil)

Not suitable for the compost heap

Plants that have recently been sprayed with pesticides or herbicides

Meat scraps (they may attract rats and other pests)

Large amounts of diseased material

Branches with hard prickles or thorns

Persistent perennial weeds, such as striga and couch grass (burn them, or cut them and lay them in the sun to dry, then add to the heap)

Metal, plastic and other non-organic materials

Box 5.4. Living organisms involved in composting

Most of the living organisms involved in composting are so small that you cannot see them. To survive they need water, air and organic material, which is their food. These living organisms feed on the organic matter and produce carbon dioxide, water and heat.

Compost piles go through three main phases:

- **Hot phase.** This is when the pile heats up. It is hottest in the centre. The heat kills disease germs and weed seeds.
- **Cooling down.** Fungi break down tough fibrous material such as crop stems.
- **Ripening.** Termites and worms help break down and mix material.

In a hot climate, the living organisms work harder and break down the materials faster than in a cold climate. The types of organic matter and the soil acidity also affect the rate of decomposition.

Box 5.5 Using worms to make compost

Vermicomposting uses earthworms to break down waste materials and turn them into compost. It uses special types of earthworms. They live in litter or dung rather than in soil. The most widely used species are:

- Red worm (*Eisenia andrei*)
- Tiger worm (*Eisenia fetida*)
- African nightcrawler (*Eudrilus eugeniae*)
- Oriental compost earthworm (*Perionyx excavatus*).

Where to put the compost pile?

- Somewhere where it is easy to carry the materials you collect, and close to the where you want to apply the compost.
- In a shady, sheltered area (e.g., under a tree) to avoid too much evaporation.
- Near a source of water – such as where you do the washing. If this is not possible, keep a jerry can near the heap.
- Near a livestock pen. Adding dung and urine to the compost helps make good compost.
- Not too close to the house. Compost piles smell, and they attract vermin.
- Under raised chicken or rabbit cages, so that dung and urine are continually added to the pile.

► *Exercise 5.6 Building a compost heap*

Applying compost

Compost can be used as soon as most of the original material is no longer recognizable, and it has turned blackish brown and has a pleasant smell. This should be in 1.5–2 months.

Apply the compost at least 2 weeks before sowing or planting. That prevents the compost from harming the germinating seeds.

Compost is generally scarce, and it is heavy to carry around. So it is best to apply it in spots where the crops can reach it. For example, you can put a large handful in each planting hole before you sow maize. You can also put it in furrows: 1 bag is enough for a plot of 10 m by 10 m (► *Module 7*). You can also put it in a ring around trees, over where the roots are.

Keep the compost moist, but not wet, while you are waiting to use it.

Don't wait too long. Compost continues to ripen, and after a few months it will lose its quality as a fertilizer. Providing it is protected from sun and rain, it will still improve the soil structure and water-holding capacity.

Mulch

Mulch is leaves, grass, twigs, crop residues or straw, spread on the soil surface. It can be spread on a seedbed and around planting holes, or applied in strips. It protects the soil, traps moisture, and encourages soil life (*Box 5.6*).

Many different materials can be used as mulch: crop residues, cover crops, grass, waste from agricultural processing, tree prunings, and weeds.

Materials that decompose easily (such as leaves) protect the soil for a short time only. Harder materials, such as straw, will stay longer on the soil and protect it better from erosion.

Figure 5.9. Putting compost in furrows

When and how to apply mulch?

Apply mulch at the start of the rainy season, when the soil is most vulnerable to erosion. If it rains only a little, the mulch may soak the water up and then let it evaporate, so that the soil does not get wet.

You can apply mulch before or after planting. Once the crop canopy has completely covered the ground, mulch is no longer needed.

Box 5.6. Benefits and constraints of mulch

Benefits

- Mulch protects the soil from erosion
- It lets rain seep into the soil
- It shades the soil and keeps it moist
- It feeds and protects living organisms
- It suppresses weeds
- It protects the soil from the hot sun
- It releases nutrients while decomposing, so fertilizing the crop

Constraints

- Not enough mulch may be available
- Mulch can encourage pests and diseases
- It can contain weed seeds. Do not use weeds as mulch if their seeds are a problem. Rotate crops to reduce such risks
- Dried grasses may catch fire
- Some grasses can take root and become weeds, or harbour pests and diseases
- Mulch is difficult to use on steep land
- Crop residues used as mulch cannot be used to feed animals

If you apply a thin layer of mulch, you can sow seeds directly through it, for instance using a jab planter or planting stick. At higher altitudes, apply a thin layer, as a deep layer can delay germination by keeping the soil cold.

If you use a deep layer of mulch to suppress weeds, apply it after the crop has emerged. As fresh mulch decomposes, it may harm a young crop. So it is better to let the mulch wilt or dry before you apply it.

You can also apply mulch to crops that are already growing. Spread it between the rows, directly around single plants (especially trees) or evenly over the field. Avoid mulching too close to the plants to discourage pests and diseases.

If it is windy, cover the mulch with a layer of soil to stop it from blowing away.

Termites may be a problem, especially in hot and dry places. Termites may eat the mulch and sometimes even the crops. But termites do have advantages: they dig burrows that improve the soil's ability to absorb water. They leave behind soil casts that are rich in nutrients. And as long as they attack the mulch and do not touch the crops, there is no problem.

► *Exercise 6.3 Living with termites*

► *Exercise 6.9. Maximizing soil cover to increase biological activity*

► *Exercise 10.6 Mulching to reduce evaporation*

Green manure

Green manures are crops that are grown mainly to produce organic matter, which is then worked into the soil. They produce a lot of organic material in the field (no need to carry it around!). But in hot, moist conditions, they decompose very quickly when they are ploughed in, so a lot of nutrients escape into the air.

Do not sow the main crop too soon after incorporating a lot of green manure (or too close to it), as it can burn the seeds or young plants.

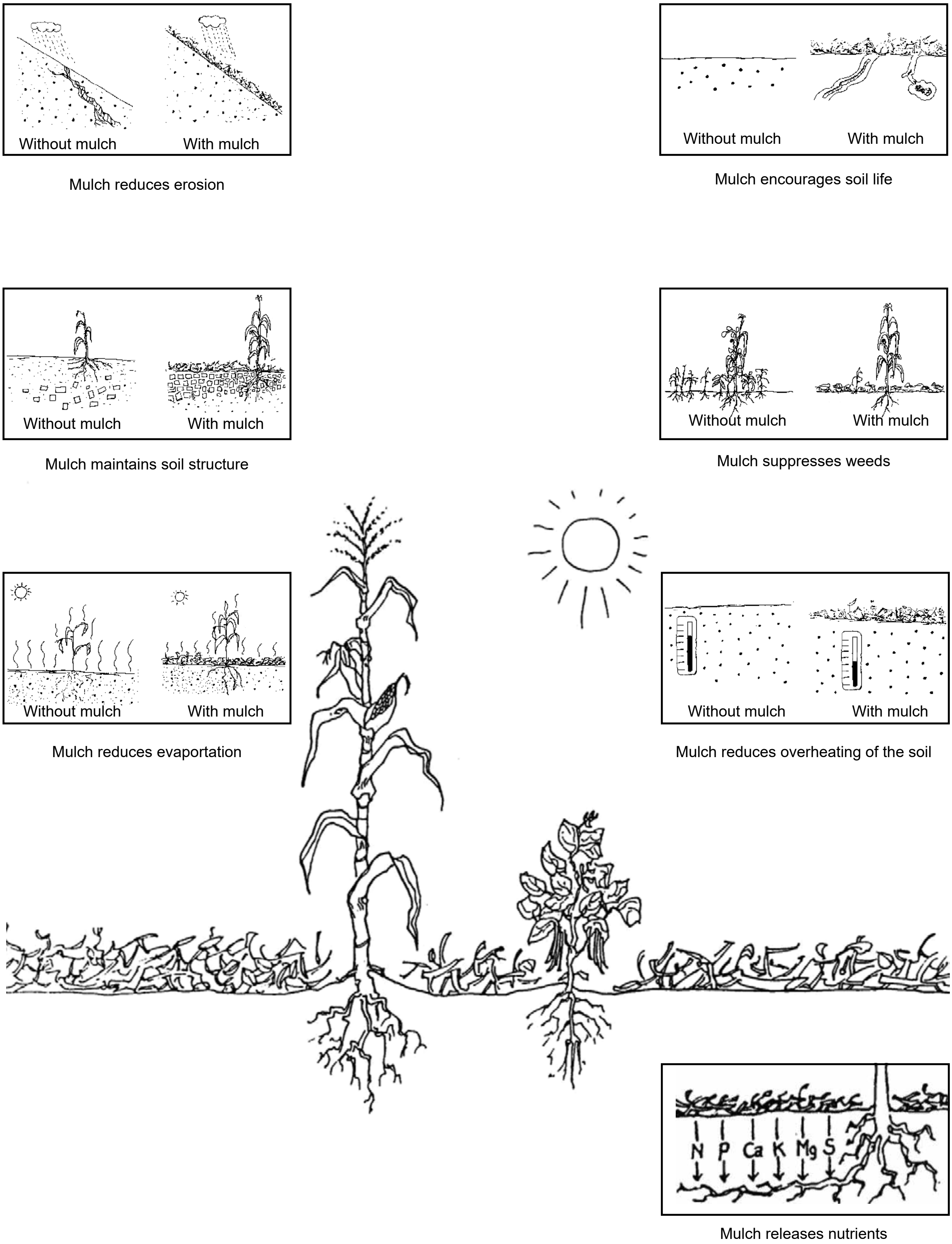


Figure 5.10. What is the use of mulching?

Source: Müller-Sämann and Kotschi (1994)

Cover crops

Cover crops are grown mainly to protect the soil. They reduce evaporation, keep the soil temperature even, protect it from raindrops, and prevent erosion. They also suppress weeds.

Cover crops are used in conservation agriculture (► *Module 8*).

You can use the same species as cover crops and green manures. Most cover crops are fast-growing leafy species that fix nitrogen (► *Module 6 Encouraging soil life*). Examples are *Mucuna*, *Canavalia*, *Crotalaria*, lablab (*Dolichos lablab*) and pigeonpea (*Cajanus cajan*).

Crop rotations, crop mixtures, and agroforestry

Crop rotations, crop mixtures and agroforestry are very important ways of managing organic matter.

- **Crop rotations** mean growing different crops from one season to the next, one after the other. It is often a good idea to grow a cereal (such as maize or sorghum) one season, then a legume (such as beans) the next.
- **Crop mixtures** mean growing different crops in the same field at the same time. For example, a farmer may grow maize, beans, squash and bananas in the same field.
- **Agroforestry** means growing trees and shrubs in the fields, around their edges or in separate plots, alongside the crops.

Farmers can choose from various crops those that suit them best. For example, they may select:

- Grasses that have deep, dense roots.
- Legumes that produce a lot of leaves and grow quickly.
- Leguminous trees and shrubs as a hedge around the field.

Crop rotations are covered further in ► *Module 8 Conservation agriculture.*

Optimizing nutrient recycling

As soon as land is brought into cultivation, the amount of organic matter drops quickly for three reasons:

- Less organic matter is added to the soil.
- The soil is warmer, so organic matter decomposes faster.
- Tillage exposes the soil to the sun, air and rain, further encouraging decomposition.

If the farmer does not add organic matter, the soil fertility will gradually fall until the soil is no longer productive. In some soils, this may happen after only a few years.

Stopping the loss of nutrients is like trying to stop a car rolling down a hill. At first, it is quite easy to stop it. But once it has gathered speed, it is much more difficult. When it has reached the bottom of the hill, it is almost impossible to push it back up the hill.

Organic matter in the soil is like money in the bank. It supports the farmer's livelihood. The more organic matter, the better the farmer's standard of living. But if someone only draws out money from the bank without investing it, even the richest person will become poor.

It is important to put money back into the bank – and to put organic matter back into the soil to maintain the soil's ability to produce crops.

More on nutrient resource management in ► *Module 7*.

Exercise 5.1 Observing soil organic matter

The amount of soil organic matter varies from soil to soil. It depends in part on the past land use. This exercise shows a simple way to assess the health and productivity of a soil. This exercise can also be used to compare the topsoil (top 5 cm) and subsoil (below 20 cm).

Learning objectives

Compare organic matter in different soils.

Understand the importance of organic matter in soils.

Understand how organic matter gets into soils.

Timing

Preferably during the dry season. The soil may be too wet in the rainy season.

Preparation

–

Duration

1 hour.

Materials

Spade or hoe, kitchen knife, magnifying glass (see if you can borrow one from a school).

Steps

1. Ask the participants to choose two soils they think will differ in their organic matter content: for example, forest or fallow versus a cropped field; or a zero-tillage field versus a conventionally tilled one.
2. Use a spade or hoe to cut out a block of each soil, about 15 cm square. You can do this by first digging a hole, then carefully cutting out a block of soil from next to it.
3. Check the following (use the magnifying glass to see details if have one):

- The leaf litter on the surface
- The different layers in the soil
- The soil colour and how it differs from layer to layer
- The distribution of humus (dark material)
- The number and size of pores, and the amount of compaction
- The density and depth of roots
- Signs of earthworms (burrows) and other living organisms
- The structure of the soil and the presence and shape of soil crumbs.

4. Compare the two soils.
5. Invite the participants to discuss the differences between the two soils.

Questions to stimulate discussion

- Why is there more litter at the forest/fallow site than in the field?
- Why are there more soil animals in the forest/fallow soil? Why is the topsoil darker?
- What happens to leaves and dried grasses in the forest/fallow soil?
- Why are there more and larger pores in the forest/fallow soil than in the cropped soil?
- Why are large pores important?
- How do the pores affect the loss of rainwater, the loss of nutrients and fertilizers, erosion?
- What do roots do for a plant? What happens to water taken up by roots? What happens to nutrients they absorb?
- What happens to nutrients in dead leaves on the soil surface?
- How can a cropped soil be transformed so it looks like the one from the fallow/forest?

Learning objectives

Determine the stability of soil aggregates.

Observe what happens when soils are saturated with water.

Understand that organic matter stabilizes the soil structure.

Understand the impact of organic matter on soil erosion, surface sealing, crusting and runoff.

Timing

When discussing the importance of organic matter in relation to soil erosion.

Preparation

Immediately after ► *Exercise 5.1 Observing soil organic matter*. Use the soil blocks you collected for this exercise.

Duration

1 hour.

Materials

A piece of heavy cloth, two glass jars, scissors, water.

Exercise 5.2 Organic matter as glue

This exercise shows that organic matter is like glue. It binds soil particles together. It improves the soil structure and helps it resist erosion.

Steps

1. Fill the jars with water.
2. Cut two strips of cloth, 15–20 cm long and a little narrower than the neck of the jars.
3. Put one of the cloths on the open neck of each jar so the middle sits on the water, and the two ends hang over the sides.
4. Put a small clod of soil on the cloth.
5. Do the same for the other jar, using a clod from the other soil.
6. Look at what happens to the clods. Soils low in organic matter will fall apart and disperse quickly in the water.

Questions to stimulate discussion

- What happened in the two jars?
- Which water is clearer?
- What will happen to soils that are low in organic matter during a heavy rain shower?
- Where will this soil go?
- What can improve the organic matter content of the soil?

Notes

Recall what happens when rain splashes and water runs off the soil (► *Exercise 10.8 Soil cover to reduce erosion*). Now look what happens to the soil clods in the jars. How will the level of organic matter affect what happens when raindrops hit the soil, and when water runs off? Which soil is more easily eroded? How about sealing and crusting of the surface?

Discuss what can be done to prevent these things from happening.

Exercise 5.3 Decomposition of organic materials

Some soils contain more soil life than others, so break down organic matter faster. This exercise helps participants understand that more organic matter means more soil life, which means that plant residues are broken down more quickly.

Steps

1. Ask the group to choose three places with different types of soil: one should be high in organic matter (darker in colour), one should be low in organic matter (lighter), and the third soil should be in a paddock where there is old manure. For the first two, you can use the same sites as in ► *Exercise 5.1 Observing soil organic matter*.
2. Take several armfuls of leaves from a garden. Wash them with clean water. Divide them into three equal piles.
3. Put the leaves into the bags or cloths, and tie each bag or cloth into a bundle with string.
4. Bury the bags, one in each of the three places.
5. After two weeks dig up the bundles. Open them and look at their contents.
6. Bury them again in the same place.
7. Dig them up again each week to examine them.

Questions to stimulate discussion

- Are there any obvious differences between the bags in the different places? Where have the leaves decomposed fastest? Where is slowest? Why?
- What has happened to the leaves in the bags? Have they been attacked? By what? Fungi? Bacteria?
- Why is breaking down of organic matter important for the soil and crops? Whose job is it to start the breakdown?

Notes

Instead of burying the bags in three places, you could bring soil from the three places and put it into three big pots. You can then bury the bundles in each of the pots.

Learning objectives

Understand that soils rich in organic matter break down plant residues more quickly than soils with less organic matter.

Understand that soil life uses and transform organic matter.

Timing

Preferably at the beginning of the dry or rainy season, when the soil is still moist, but not too wet nor dry.

Preparation

See steps 1–3.

Duration

Initial set up: 2 hours.

Follow up: briefly each week for 6 weeks.

Materials

Three small mesh bags, pieces of mosquito net or large-mesh cloth (with holes big enough for earthworms and small beetles to get through), each about 40 x 40 cm; string, notepaper, pencils.

Adapted from

Settle (2001)

Exercise 5.4 Sources of organic material

Learning objectives

Discuss ways to increase the supply of organic materials, and how to use them on the farm.

Timing

Any time.

Preparation

–

Duration

2–3 hours.

Materials

Large sheets of paper, marker pens.

We often neglect valuable organic materials. We think of them as rubbish, throw them away or burn them. This exercise helps participants identify major types of organic materials on the farm and check their value for crops.

Steps

1. Divide the participants into groups of 3–5.
2. Ask each group to think of possible sources of organic materials in and around the village. How are they normally used?
3. Ask each group to think of how they could get more organic materials for the farm. How might they reduce the use of crop residues for fuel and fodder, so they stay in the field?
4. If local people burn crop residues when preparing the land, what nutrients might be lost?
5. Give the groups 1.5 hours to discuss. They can use the markers and paper to take notes.
6. Ask one member from each group to present the group's findings to everyone.
7. Allow 1.5 hours for a general discussion on ways to increase the supply of organic materials.

Questions to stimulate discussion

- What organic materials are available on the farm?
- How are they used at the moment? As fuel, fodder, thatch, or other purposes? Does this mean they cannot be used as an organic fertilizer?
- Are there other sources of fuel or fodder that could be used instead of crop residues?
- Are there organic materials on the farm that are not currently used?
- Are there any food industries nearby (sugar or cereal mills, coffee processors, etc.)? Do they have any by-products the farmers could get?
- Are there any other materials the farmers could get from outside (grasses, leaves and prunings from the forest, etc)?

Exercise 5.5 Making liquid manure

Liquid manure is easy to make and use. This exercise shows farmers how.

Steps

1. Fill the bag with animal manure or easily decomposable plant material (e.g., leaves of leguminous trees). You can mix manure and leaves if you wish. Tie the neck of the bag with the string.
2. Put the bag into the drum of water, cover it with the lid, and leave it to ferment.
3. Every 2–3 days, stir the water. This gets the living organisms working and releases nutrients into the water. Keep the lid on the drum the rest of the time.
4. After 3–4 weeks, take the bag out of the drum. Add twice as much the water to the liquid in the drum. Then use a watering can or bucket to pour it on the ground around crops in the garden.

Questions to stimulate discussion

- Do farmers in the area already make liquid manure? What do they use as starting materials? Does the manure work? If not, why not?
- Do farmers think it is a good idea to make liquid manure? Does it take much work? How much does it cost?
- What is the best way to use the liquid manure?

Notes

Don't apply liquid manure directly onto plants that you eat fresh, like lettuce.

Learning objectives

Make and use liquid fertilizer.

Timing

3–4 weeks before the fertilizer is needed in the garden.

Preparation

Find a convenient source of animal manure and easily decomposable plant materials, like leguminous plants.

Find a vegetable garden where the liquid manure can be tested.

Duration

1–2 hours to prepare the liquid manure.

3–4 weeks for fermentation.

1 hour to apply the fertilizer when it is ready.

1 hour, a month after the application, to compare fertilized and non-fertilized crops.

Materials

A jute bag, a piece of string, animal manure or leaves, a big drum of water with a lid.

Adapted from

IFOAM (2002)

Figure 5.11. Making liquid manure

Exercise 5.6 Building a compost heap

Learning objectives

Produce compost out of locally available materials.

Timing

Make the compost in the dry season so it is ready for planting time.

If there is not enough water in the dry season, make compost during the rainy season, but keep it sheltered to stop it from getting too wet when it rains.

Preparation

Check that all the materials can be found nearby.

Decide where to make the heap.

Duration

3 hours to start the heap.

Season-long maintenance.

Materials

Ingredients for the compost heap: manures, crop residues, grass, leaves, weeds, lime, rock phosphate, wood ash, etc.; 30–40 wooden or bamboo stakes, roughly 1.5 m tall and 4–5 cm thick; plastic twine, large knife, wheelbarrow, water, plastic tarpaulin or banana leaves (if available).

Adapted from

Settle (2000), CABI/FAO (2000) and IFOAM (2002)

Composting is a good way to use organic material and add organic matter to the soil. This exercise shows farmers how to do it.

Steps

1. Discuss whether the participants make compost. What do they do? Can it be improved? How?
2. Collect materials you can add to the pile. Look at the colour – is it soft and green (will decompose fast), or hard and brown (will take longer). Chop up the bigger pieces to speed up the composting process.
3. Collect other materials – animal dung, ashes, farm by-products, feathers, rock phosphate, kitchen waste, and soil.
4. Bring all the materials to where you want to build the compost heap.
5. Measure out an area about 1.5 x 1.5 m for the heap. Push a big stake into the ground at each corner.
6. Push the other stakes into the ground to make a square cage, leaving gaps a few centimetres wide between the stakes. Tie branches and twine horizontally from each of the four corner posts to make the cage strong.
7. Discuss the different types of materials and their importance.
8. First put a layer of coarse plant material such as stalks or twigs into the cage. Then add thin layers of other materials (► *Figure 5.12*). Before adding each layer, sprinkle some water on the material to make it moist (but not wet). Mix the water in, like mixing cement, then add the material to the pile. Make the layers of plant materials about 10 cm thick; manure 2 cm thick, and soil just 1 cm.
9. Carry on adding layers until the heap is at least 1 m high (you can make it higher if you have enough material).
10. When you have finished, push 4–6 long poles in different places down to the bottom of the pile. That will create air channels to the centre of the pile.
11. Cover the heap with grass, sacks or banana leaves.
12. Turn the heap every 2–3 weeks. When turning, take the heap apart completely. Build it up again on a base of coarse material. Put the drier, and less decomposed parts in the middle of the new heap.
13. It may take several months before the compost is mature. You can use it as soon as most of the original material is no longer recognizable. It should be crumbly, brown or blackish.

Questions to stimulate discussion

- What happens with weed seeds, insect eggs and cocoons, and disease spores inside the compost heap?
- When is it better to compost crop residues rather than digging them in?
- Do farmers in the area make compost? If yes, what do they use it for? If not, why?
- Would it be economical for farmers to make compost?
- What is the best way to use compost on your farm?

Notes

- During the dry season, cover the heap with a thin layer of soil to reduce evaporation and stop flies from breeding. If water is scarce, consider making compost in a pit to minimize the water loss.
- During the rainy season, turn the heap after every rainstorm until it is moist throughout. Then cover it with a plastic sheet, grass or mud so that the rain does not cool it down.
- The stakes are not necessary for a compost pit, or if the pile is built carefully.

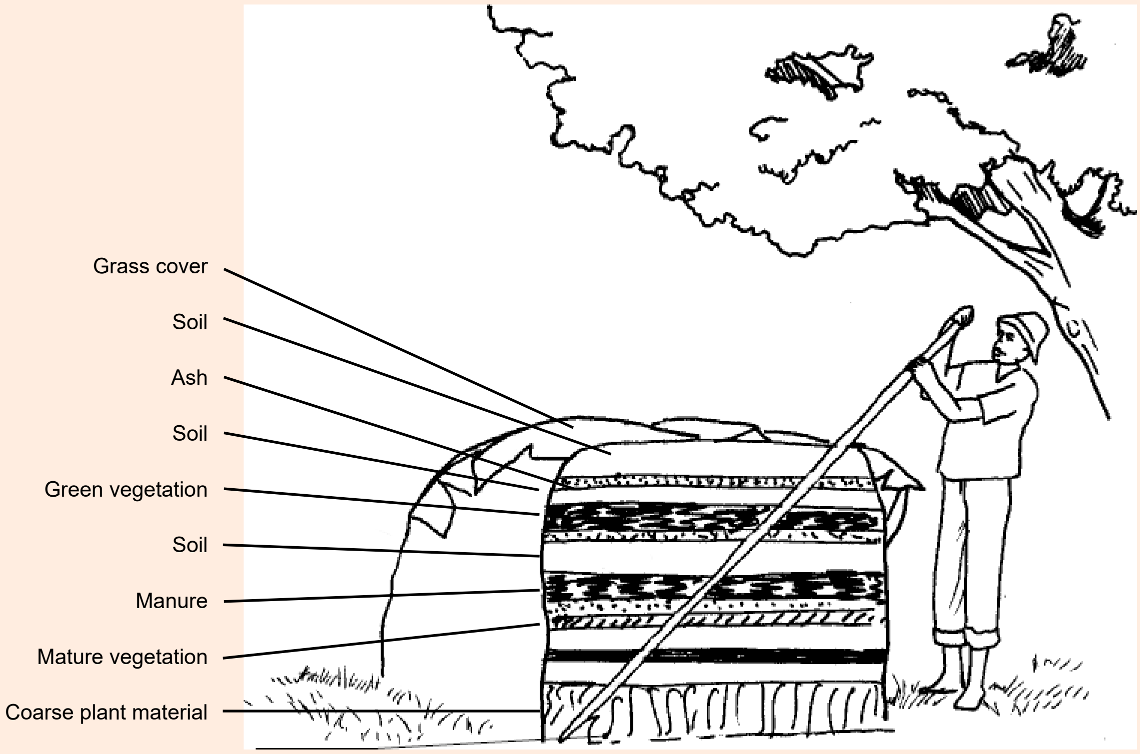


Figure 5.12. Building a compost heap

Module 6. Encouraging soil life

Healthy soils are living soils. They are productive for crops and livestock. They provide few problems for cultivation, and have few soil-related pests and diseases. The millions of organisms that live in the soil maintain the soil structure and recycle nutrients. The more of them, the better. This module aims to help farmers understand how important a living soil is.

Many farmers think of living organisms in the soil as a problem, in the same category as pests and diseases. This module emphasizes how a healthy soil improves productivity and reduces the effects of soil-related pests and diseases.

Learning objectives

After studying this module, you should be able to:

Understand what a healthy soil is.

Understand the range of organisms living in the soil, and what they do – even if you cannot see them with the naked eye.

Appreciate that healthy soils sustain crops and livestock.

Understand how roots show whether the soil is healthy and productive.

Living soils

We often think of soils as simply somewhere where plants grow. We know they provide water and nutrients to plants. Many farmers regard living organisms in the soil as pests (think of termites and nematodes), or as having no value.

But soil is much more than that. It is dynamic and living. Most life in the soil is too small to see: we need a magnifying glass or microscope to see it. But even though they are small, these organisms make a major contribution to soil fertility, structure and stability. They contribute to the productivity of our land and prevent it from degrading. A healthy, living soil is vital for our environment and livelihood.

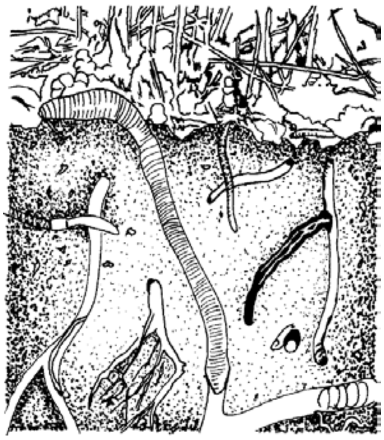


Figure 6.1. A healthy soil is full of living organisms

Characteristics of healthy soil

- A healthy soil has a good, crumby structure. Roots hold the soil and prevent erosion, and plants protect it from heavy rain that forms a hard surface.
- A healthy soil contains many air spaces that allow roots and living organisms to breath and grow. In compacted soils, roots cannot grow well. Plants growing on waterlogged soils often become yellow and die: they suffocate.
- The soil is soft and easy to till. It allows roots to grow well and reach moisture and nutrients easily.
- It allows rainwater to soak in easily, and holds it for plants to use.
- It filters water and produces clean water in streams, rivers and wells that is safe to drink.
- It has few hard-to-control weeds, like *Striga* (which is common in infertile soils), weeds that grow on acid soil, spreading weeds like couch grass, or species that livestock cannot eat. ► *Module 13 Managing weeds*.
- It quickly neutralizes harmful bacteria in animal and human excreta.

Soils under natural vegetation or fallows are usually healthy soils. But a few years of cultivation can make them hard and unproductive, with lots of pest and disease problems.

The soil's health depends on how we care for and nourish it. If soils are starved and mistreated, they will not be productive. The way the farmer

Table 6.1. Properties of a healthy and a poor soil

Healthy soil	Poor soil
Litter or plant fragments on the surface	Bare, compacted surface
Dark colour because of organic matter	Light colour because the soil is starved
Crumby structure	Weak soil structure (dense but breaks into particles)
Open structure with pores and channels for air and water	Compact soil with poor aeration and drainage (what happens to plants and animals if we shut them in an airtight box?)
Lots of fine roots holding the soil together	Few roots, or roots of problem weeds
Channels made by earthworms and termites	Few channels or large pores
Many visible living organisms, many different species (look for the burrows they make)	Few visible living organisms, or sometimes a lot of the same (e.g., many white grubs)

manages the soil – the crops grown, the tillage practices, the use of compost and manure – all these affect the living organisms in the soil.

The two most important things for a healthy soil are the amount of organic matter (▶ *Module 5 Using organic materials*) and the soil life it contains.

What lives in soil?

A fertile soil depends on many things: water sinking into the ground, decomposition of organic matter, the supply of plant nutrients, and so on (▶ *Table 6.1*). However, these characteristics in turn depend largely on living organisms, most of which are too small to be seen. Using tractors and agrochemicals tend to draw attention away from these natural processes. So many farmers do not understand how important living organisms are.

A healthy soil has a lot of animals because it has food and is a good place to live (air, moisture). Most animals and roots are found in the top 20 cm of the soil.

- **Larger animals**, such as earthworms, millipedes, cockroaches and termites, are found in quite large numbers. There may be tens to a few hundred in every square metre. These animals may move around on the surface or burrow through the soil.
- There are thousands of **very small animals**, ranging from the size of a rice grain down to a pinhead. You can see them if you look carefully. These live mainly in the spaces in the soil. When the soil is compacted, they cannot burrow and there are fewer of them.
- There are many thousands of even tinier animals, which can only be seen with a strong magnifying glass. These include **nematodes** that attack plant roots (the plants may become stunted and yellow). Nematodes are tiny transparent worms that look like tiny threads. But not all nematodes are pests, just as not all birds attack crops.
- The most abundant forms of life in soil are fungi and bacteria. They are tiny – too small to see even with a magnifying glass.
- We know about **fungi** that grow on damp soil and rotten wood. Some types of fungi can be eaten – we call them mushrooms. But what we see or eat is only part of the fungus. Most is buried in the soil or wood where it grows. It is made up of very fine threads (like hairs) that grow through

the soil like roots to feed and digest dead organic matter. Unlike green plants, fungi do not need light to grow, so they only emerge above the ground to fruit and produce tiny seeds or spores that look like dust. The threads grow in huge numbers. A handful of rich compost might contain more than a kilometre of threads if all were stretched out in a line.

- **Bacteria** are too small to see – a million could fit on the head of a pin! But they are very important even though they are so small. Many bacteria are useful in producing antibiotic drugs. Others turn milk sour to make yoghurt or cheese. Some bacteria cause diseases or make food rot. Just a handful of soil may contain more different types of bacteria than all the animals and plants in a forest. The same handful of soil will have more bacteria than there are people in a big city. There are a lot of bacteria in a healthy soil, but fewer (and fewer different types) in poor and degraded soils.

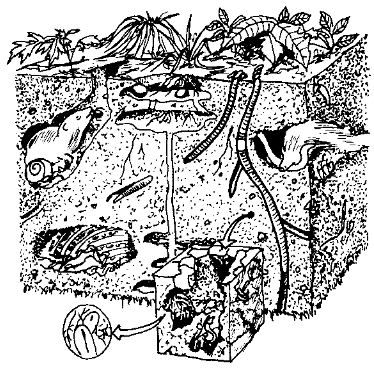


Figure 6.2. A healthy soil contains many living things

Altogether, the organisms living in a healthy soil weigh 10–100 times more than all the animals above the ground! They are doing a lot in soil, even if we cannot see most of them.

► *Exercise 6.1 The health of a soil*

► *Exercise 6.2 Comparing healthy and poor soils*

6

What do organisms do in the soil?

All these animals, fungi and bacteria are hard at work. They have a big influence on the chemical and physical properties of the soil (► *Module 4 Knowing your soil*).

When we walk in a forest, we rarely see diseased plants or sick wild animals. That is because the interactions between different types of living things keep the community of plants and animals as a whole healthy (► *Module 14 Managing biodiversity*). There is a balance. Diseases rarely break out, and when they do, they usually affect only a small area and are quickly brought under natural control. Many different sorts of birds, butterflies and plants are a clear sign that the area is healthy – though we may not understand what each bird or butterfly does. In the same way, most of the soil life has its own role to play to keep the soil healthy, without us even noticing them.

These animals, fungi and bacteria are part of a very complex community.

- Some organisms feed on dead plant materials. Like cows, they eat plants!
- Others, called **predators**, feed on the plant-eaters – just like lions do.
- Still other organisms are **parasites** – just like mosquitoes and fleas.

In fact, life in the soil is quite like life above the ground.

Most farmers know that predators and parasites of pests are their friends. They help control pests and keep plants healthy. But it can be hard to think of the same thing happening underground, with living organisms that are so small we cannot see them. When their plants do not look healthy, farmers should look at the crop roots, as an unhealthy soil can lead to unhealthy plants.

The soil animals that are big enough to be seen (beetles, earthworms, ants, etc.) are important because they change the structure of the soil and mix nutrients in the soil. Roots are also important to maintain the structure, and they bring nutrients and water up from deep in the soil.

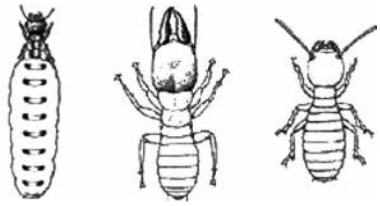


Figure 6.3. Different types of termites:

Dead plants, animals and dung would not decompose without soil life. These living organisms break down the organic materials and produce humus and many of the nutrients that plants use as food (► *Module 5 Using organic materials* and *Module 7 Managing plant nutrients*).

Some bacteria (called **Rhizobia**) fix nitrogen from the air. Certain fungi (called **Mycorrhizae**) work with roots to collect phosphorus and other nutrients in poor soils.

► *Exercise 5.3 Decomposition of organic materials*

Termites

Termites are social insects, like bees. They live in colonies. A termite colony has several different types of termites. Like bees in a hive, there is a queen, workers and soldiers. There are more than 2000 species of termites, but only about 200 of them are pests.

We can divide termites according to the types of food they eat. Some eat wood and litter; others eat soil, and some eat grass.

Termites that eat wood and litter

These termites are often found in drier areas. During the dry season, they go out in search of wood, dead grass and dung. They cover this food with a layer of soil, which they dig up from deep underground. This termite soil is rich in minerals such as iron and zinc, and is good for plant and soil health.

The termites carry the food away to their nest. This may be in a mound, or hidden underground. It may be up to 200 metres away! In the nest they grow a fungus that helps them digest the food. Sometimes we find the "fungus combs" (little ash-coloured balls) made by one type of termite. The termites can dig quite big burrows that can become important channels for water. When the rains start, water runs into the burrows and seeps into the soil instead of running off the surface. You might be able to see this drainage happen on a gentle slope where termites have been feeding on maize stalks.

Farmers sometimes think that these termites are pests because they attack maize and other woody crops during a drought. This happens mainly because there is no other food for them. But most of the time they provide a valuable service. Leaving mulch on the fields feeds the termites, reduces termite attacks on the crops, and improves the soil.

► *Exercise 6.3 Living with termites*

Termites that eat soil

In humid areas, many termites feed on organic matter in the soil. They never attack crops or other living plants. They are entirely beneficial for soil fertility.

Part of the phosphorus in the soil is "fixed": it cannot be used by plants directly, because soil particles hold it very strongly. When termites digest this soil, they release the "fixed" phosphorus, and plants can use it. In parts of West Africa, farmers look for the mounds of these termites. They know that the soil around the mounds is fertile.

Termites that eat grass

Some types of termites like to eat grass. They collect grasses during the dry season, and store these in their mounds for the wet season. They also dig tunnels that help rainwater seep into the ground.

It is almost impossible to get rid of termites completely. So look for ways to get benefits from them and reduce the harm they do.

Earthworms

There are three main types of earthworms:

- Some earthworms live in the soil surface and feed on litter. They are generally **small** and are coloured **green, blue or reddish**. They move quickly. They are often found in dung and compost heaps, and are generally used in vermicomposting (► *Box 5.5*).
- Some earthworms are **large** (more than 15 cm long). Only the first part of the body is coloured (dark green, blue, brown or reddish). They dig vertical burrows. They leave tower-like casts of fertile soil on the surface.
- Other earthworms have **no colour** (sometimes they are pink or slightly brown, because of the soil they have eaten). They are very important in creating and maintaining the soil structure.

If there are a lot of earthworms (especially if all three types are found), the soil is considered healthy and has high amounts of organic matter.

Earthworm burrows help rainwater seep into the soil, and their burrows let it drain through the soil. Earthworms do not move about much. They turn over the soil and plant materials in the same place. So they make a more porous soil structure than termites. This is good for roots and water movement. The casts are rich in organic matter and plant nutrients. This is because earthworms choose the best-quality organic matter as food – just like a cow that eats the juiciest leaves will produce good quality dung.

Farmers should create a good place for earthworms to live. They can do this in several ways:

They can feed the soil with manure or plant materials (► *Box 6.2*).

They can avoid intense, repeated tillage, because that kills earthworms and destroys the soil structures they have built. Earthworms do not thrive if the soil is tilled. Earthworms are important in restoring the soil in conservation agriculture. ► *Module 8 Conservation agriculture*.

They can plant cover crops that protect the soil from the hot sun.

One way of making compost is by adding certain types of earthworms to the compost pile(► *Box 5.5*).

► *Exercise 6.4 Earthworms in action*

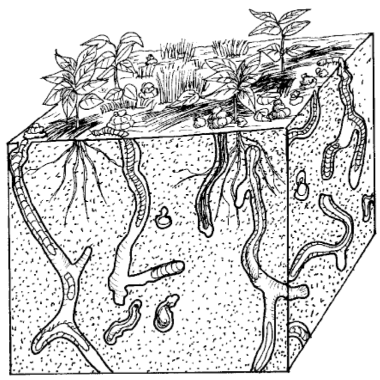


Figure 6.4. Air and water can get into the soil through the tunnels made by earthworms

Nematodes

Nematodes are tiny thread-like worms that occur in vast numbers – many millions per square metre in most soils. Hundreds of different types of nematodes exist, but there are four main categories:

- Some nematodes **live freely** in the soil. They are good for farming: they feed on bacteria and fungi, so help control harmful organisms and release

Box 6.2. Giving food and shelter to earthworms

Earthworms work best if they have both food and shelter. Applying a combination of Glyricidia prunings and rice straw mulch on the soil attracted a lot of earthworms, a study in Sri Lanka showed. Because of the earthworms, rainwater seeped into the ground a lot faster than elsewhere.

Glyricidia or rice straw by themselves were not as good as a combination. The Glyricidia prunings attracted lots of earthworms at first, but it decomposed quickly, and they soon wriggled away again. The rice straw provided shelter, but not much food for the worms. The combination of prunings and straw was best: worms like to live well!

Source: PT Bandara & JM Anderson (unpublished data).

Try to have lots of friendly living organisms in the soil, and few harmful ones.

nutrients for plants. When it is hot and dry, they become dormant. As soon as there is some water, they quickly wake up and resume work.

- Some nematodes **prey on other soil animals** (including other nematodes).
- Some are **parasites** on other animals, including white grubs and other insects.
- Others **feed on plants** and may seriously damage crop roots.

A healthy soil under natural vegetation has lots of all these types of nematodes. But none are dominant, because there are many different types of plants, and the other animals and microbes in the soil keep a balance. But farmland has less diversity. Particularly if one crop has been grown in the field for many seasons, this natural regulation is lost. Particular types of nematodes can then become a problem and seriously damage the crop.

Nematode attack can be seen in the field: sick plants with yellowing leaves, growing in sparse stands. Check the roots: stunted roots often mean nematode attacks. For example, a carrot may have a stunted and much divided taproot with a mass of fine roots. The side roots of Irish potatoes may have things that look like galls. Banana plants might have rot in their rhizomes (roots), and will bear only a few, small fruits. Beware, though: many other things can cause symptoms like these, not just nematodes.

Nematodes are difficult to see and diagnose without a powerful microscope. They can be hard to treat without expert advice. So we can give only an introduction here.

Because nematodes are so small and breed very fast, it is very difficult and expensive to control them with pesticides. Here are some biological methods of controlling nematodes.

- **Rotate crops.** Rotate susceptible crops with other crops that are not attacked. That will reduce nematode numbers or even get rid of them entirely. Crop rotation controls many pests and diseases, and is generally the first choice for farmers. For example, you can plant a different crop for three years to get rid of nematodes that attack bananas. Rotation sometimes does not work, though, as some of the most important nematode pests attack many different plants, including weeds. That means you may have to combine crop rotation with other control measures.
- **Clean farm implements.** Nematodes cannot move more than a few inches a year. They are mainly spread by people! Be sure to clean soil from hoes and other implements before you take them to other fields.
- **Choose healthy propagation material.** Banana rhizome rot is caused by nematodes and is spread through suckers – so use only healthy suckers.
- **Choose nematode-resistant crop varieties**.
- **Apply organic manures.** Organic manures encourage certain fungi and bacteria that in turn hinder nematodes. Applying fresh animal, poultry or green manure may greatly reduce nematode attacks. Something for the farmer field school to try out?
- **Use enemy plants.** Some nematodes do not like the fluids from the roots of certain plants. So planting these plants as a rotation (or better still, an intercrop) can fight nematodes.
- **Sow trap crops.** Oats is a good **trap crop** (a plant that attracts pests and keeps them away from the main crop) for the wheat knot nematode, which attacks wheat and barley. The oats should be ploughed in before the nematodes mature. ► *Module 13 Managing weeds.*

- **Sterilize the soil.** If you have a homegarden or a small plot where you grow vegetables, it may be worth sterilizing the soil. You can get chemicals to do this, but they are expensive and can harm your health. Another way is to sterilize the soil with help of the sun. This helps control certain nematodes, as well as soil-borne diseases and weed seeds.

How to sterilize the soil with the sun

Cover the soil when it is moist with clear plastic sheets. The best time to do this is during the hot season, when there is plenty of sun. The sun heats up the soil through the plastic, which stops the heat from escaping. Weigh down the edges of the plastic so it does not let heat out, and repair any holes. Leave the plastic on the soil for at least 4 weeks (longer if there is less sunshine or if the temperature is cool).

Ploughing before laying the sheets down may bring nematodes to the surface so the heat can kill them.

After you remove the sheets, let the soil cool down for at least a few days before sowing seed.

► *Exercise 6.5 Nematodes*

Box 6.3. Stopping damping off with the sun

Here's another way to use the sun to kill harmful soil diseases.

A farmer from Jessore, Bangladesh, had trouble with damping-off disease in his nursery seedlings. So he took some soil, mixed it with cow dung and water, and put it in plastic bags. He put the bags in the full sun, some on top of his roof, and left them there for about 2 weeks. Then he used the soil to prepare a raised nursery bed where he sowed his seeds. He had no trouble with damping-off (source: FAO, 2000; Cabbage Ecological Guide).

Another idea for farmer field schools to test: try using well-rotted compost and manure to reduce fungal diseases. The compost and manure contain a lot of other fungi, bacteria and tiny soil animals that compete with or feed on harmful fungi.

Beetles

There are many different types of beetles. Some eat plants. Some eat animals. Still others eat decaying vegetation. If you see many different sorts of beetles, you can be sure the ecosystem is healthy.

Look especially for these types of beetles. Two of them are enemies of the farmer, while one is a friend.

- The larvae (young) of **dung-beetles** are common in many places where farmers keep animals. They bury cow dung in the soil, so plant roots can reach the nutrients more easily.
- **White grubs** are the larvae of certain beetles. They may be abundant in grasslands, and they eat the roots of living plants. So they are a pest. In healthy soils, ants prey on these grubs and keep them under control.
- **Weevils** are tiny beetles that farmers know well – they damage crops after the harvest. Some weevil species also live in and on the soil (*Box 6.4*).

Box 6.4. Controlling sweet potato weevil

Farmers in Cuba found that ants are better and cheaper at controlling sweet potato weevil than pesticides. They filled sections of bamboo with sawdust and sugar, and put them in the forest to attract ants. When the ants had started a colony in the bamboo, the farmers took them to the fields and put them on sweet potato mounds. The ants soon left the bamboo because it was too hot, got hungry, and started hunting the weevils.

Figure 6.5. White grub feeding on living roots

Soil fungi and bacteria

Soil fungi

Soil fungi carry out the vital process of decomposition. They quickly break down materials (such as leaves) that are soft, juicy, nutritious and low in fibre. Organic materials that are tough and fibrous take longer to decompose. When fungi break down this low-quality material, they hold onto the nitrogen and use it themselves. That is good because it stops water from washing the nitrogen out of the soil. But it also means that plants cannot get the nitrogen until the fungi have released it again – when the material has been largely decomposed.

You can see this effect after ploughing a lot of maize stover or low-quality manure into the soil. At first the crops may turn yellow. This is because the fungi have fixed a lot of the nitrogen from the stover or manure. Later, the crops turn green again – when the nitrogen is released. ► *Module 5 Using organic materials* and *Module 7.*

Some soil fungi cause important diseases of crop roots, particularly seedlings (wilt and "damping off"). Others, such as the "honey fungus" are a particular problem in tree plantations, because they spread easily where lots of the same tree species grow together.

Mycorrhizae

Mycorrhizae are a special type of fungi. They have a partnership with plant roots. The plant gives the mycorrhiza fungi food, and in return, the fungi extract phosphorus from the soil and provide it to the plant. Most plants cannot get the phosphorus they need themselves – they need the help of the mycorrhizae. If there are no mycorrhizae, and no artificial phosphorus fertilizer, the plants will not grow well.

These mycorrhizae also help protect the plant against drought and root diseases. A healthy soil contains millions of mycorrhizal fungi that will naturally infect the plant roots of plants. But in dry areas, a long, bare fallow may harm the mycorrhizae and lead to the plants not getting enough phosphorus.

Mushrooms

Farmers know about mushrooms that can be eaten. So you can use mushrooms as a good way to get a discussion about fungi started. For example:

- In many countries, women farmers grow and sell straw mushrooms. Consider arranging a demonstration of how to do so for the farmer field school.
- Many edible mushrooms are found in East Africa. People especially like mushrooms that grow on termite nests. Others grow under certain types of trees – so if you chop down the tree, there will be no more mushrooms.

Bacteria

Some types of bacteria convert the ammonia or urea in fertilizers into a form that plants can use. Many farmers who use artificial fertilizers know they should not apply them in very wet weather. This is because the water may wash the nitrogen away. Or if the soil is waterlogged, bacteria will release the nitrogen and it will escape into the air. In either case, the plants will not get the nitrogen and will turn yellow.

Rhizobia

Other types of bacteria, called rhizobia, live in lumps, or "nodules", on the roots of legume plants. They take nitrogen from the air and convert it into ammonium that the plant can take up easily. This is called "biological nitrogen fixation". It occurs in the root nodules of legumes – all sorts of beans, peas such as pigeonpeas, ground-cover legumes, and trees such as *Sesbania* and *Leucaena*. Growing these plants as an intercrop or in rotation with cereals will help the cereals yield better.

Think of the soil as a partner. Care for the soil, and the soil will care for you.

Some legumes will form nodules with many different sorts of rhizobia. But others are fussier: they need a certain type of rhizobia only, or they will not form nodules. It is possible to buy already inoculated seeds so the partnership starts as soon as the seeds germinate. Improved strains of rhizobia that fix a lot of nitrogen and so increase crop yields are sold too.

When a root nodule is red on the inside when cut open (the colour of raw meat), this means it is busy fixing nitrogen. Certain nematodes also make lumps on the roots that look like rhizobium nodules – only they are not red inside.

It is possible to add rhizobium inoculant to the soil. But this is a specialist topic, so it is best to ask an expert to advise the farmer field school group about it.

There are other bacteria associated with plants that fix nitrogen, but they are less common.

► *Exercise 6.6 Living organisms in the soil*

► *Exercise 6.7 Rhizobia in legumes*

Roots

Why talk about plant roots in this module on soil life? Because they are alive, and because in many ways they act like other living organisms in keeping the soil healthy.

Roots physically bind the soil together. They help prevent raindrops from breaking down the clumps and lumps on the soil surface. They hold the whole soil together on slopes, so resist erosion. Roots release sugary substances that "glue" soil particles together, and on which "good" bacteria and fungi live. As roots grow through the soil they exert tremendous forces: they can push up road surfaces or split rocks. Roots break open solid rock beneath the soil. They release gases – as do other soil organisms – that dissolve in water to form weak acids. These acids weather the rocks and release the minerals they contain.

Roots push soil particles out of their way, making channels that remain in the soil and improve drainage long after the roots themselves have died and decomposed.

Ploughing the topsoil destroys many of these channels. It exposes fine roots to the sun and air, and allows the nutrients from the roots to escape. One big advantage of minimum tillage is that it keeps the roots and the nutrients they contain in the soil. ► *Module 8 Conservation agriculture.*

Roots are the main source of organic matter in the soil. Farmers can restore the organic matter in the soil by planting crops that have a lot of roots. The fine roots decompose easily. Some plants have fine, dense roots, so are good at stabilizing soil aggregates and forming organic matter. For example, grasses and cereals have deeper roots than legumes or root crops.

Farmers know that roots take up water and nutrients. But it is worth emphasizing two points:

- Different plants have different types of roots. Crops and weeds that live for just one season tend to have shallow roots that grow quickly in the topsoil. Plants with deeper roots can get additional water and nutrients – think of how shrubs and trees stay green during a drought, when grasses and crops are dry and brown. But a hardpan or natural hard layer in the soil may stop the roots of shrubs and trees from growing deep. ► *Module 4 Knowing your soil.*

Box 6.5. What do healthy soils do?

- They purify drinking water
- They decompose plant and animal remains
- They recycle plant nutrients
- They fix nitrogen from the air
- They form humus that holds water and nutrients
- They maintain soil structure
- They control outbreaks of pests and pathogens.

Healthy soils also contain many roots:

- They take up water and nutrients for plants
- They maintain the soil structure
- They reduce soil erosion and prevent nutrients from washing away
- They add to soil organic matter.

- These different types of roots can use nutrients from different places in the soil. For example, in a field of maize intercropped with beans, the maize roots go deep, while the beans have shallow roots that use water and nutrients between the rows. So they do not compete much with each other – giving the farmer higher yields overall.

► *Exercise 6.8 Becoming a root doctor.*

Caring for soil life

Healthy soils contain a huge number of animals, fungi and bacteria. Together, they support the life that is above the ground. They are vital for healthy crops, pastures, trees, animals and people.

Burning and ploughing can harm this important soil life. So too can applying too many pesticides or artificial fertilizers, and not adding organic matter. All these can damage the soil and lead to crop failures. The soil will lose its natural balance, and farmers will have to apply more and more chemicals to control pests.

Many farmers need to reverse this damage and rebuild the soil life in order to get good yields in the future. Traditionally, farmers used to leave the land fallow, or rotate crops with pastures. However, because of land scarcity that may no longer be possible. So alternatives are needed.

Those alternatives should include minimum tillage, crop rotation, mixed cropping, planting cover crops and using organic manures. All these replenish nutrients into the soil, help to hold moisture, improve the efficiency of fertilizers, and reduce the need for pesticides.

A healthy soil will produce more, with greater reliability and at lower cost, long into the future. Investing in the soil is like paying money into a bank account!

► *Exercise 6.9. Maximizing soil cover to increase biological activity*

Exercise 6.1 The health of a soil

This exercise compares a person's health with that of the soil. Participants list the features of a healthy soil, in contrast to sick soils. This also relates to the health of the ecosystem and of people.

Steps

1. Start off by asking "what do you think a healthy soil is?"
2. Ask participants to make a list of what they think is a healthy soil. They should think not only of the organisms (e.g., earthworms) in the soil, but also physical and chemical properties (colour, depth, moisture, if it is easily breakable, etc.).
3. Facilitate a discussion on how participants can tell whether a soil is "healthy" or "unhealthy". At this point the participants may think of living organisms in the soil as positive or negative – or maybe they are not concerned about or aware of them. In general, farmers do not pay special attention to soil life, except for pests.

Questions to stimulate discussion

- What are the features of healthy and unhealthy soils? The participants may come up with a long list. Make sure you emphasize colour, depth, the number and range of soil life, weeds, etc.
- Which types of organisms live in the soil? What do they do in the soil – are they pests? Are they good? Link these organisms to what they do in the soil: e.g., bacteria – decomposition and release of nutrients; earthworms – soil structure, etc.
- Compare human or animal health with the concept of a living soil. People and animals eat, grow, breathe, get rid of wastes, and die. This is also true for soils. While the soil itself is a combination of living organisms and non-living things, it is like a living creature in many ways. It breathes. It needs to be fed. It creates waste products. And in some ways, it can "die". Ask the group if they know of any soils that have been damaged to the point of being "dead".

Learning objectives

List the main features of healthy soils.

Understand functions of different living organisms in the soil.

Timing

When starting to discuss the importance of a healthy soil.

Duration

30–45 minutes.

Materials

Large sheets of paper, marker pens.

Adapted from

Settle (2001) and Trutman et al. (2002)

Exercise 6.2 Comparing healthy and poor soils

Learning objectives

Understand the importance of a healthy soil.

Determine how healthy a soil is.

Observe different organisms in the soil.

Understand why certain soils contain more organisms than others.

Timing

When the importance of a healthy soil is discussed.

Preparation

Identify two soils: a "healthy soil" (forest, woodlot, productive grassland or field plot with lots of organic inputs) and an "unhealthy" soil (one that farmers say is poor and unproductive).

Duration

1 hour.

Materials

Spade, two large bowls or polythene bags, small kitchen knives, teaspoons, two large sheets (white plastic is best), two smaller bowls (white if possible).

Usually, the soil is teeming with life: roots and living organisms ranging from quite large (earthworms) to so small you cannot see them (bacteria). If you see a lot of different types of living organisms, you can be sure the soil is healthy. Check for certain types of organisms to learn about the soil's chemical and physical situation.

Steps

1. Cut two blocks of soil, one of "healthy" soil and one of "unhealthy" soil. Make the block the width of a spade, and as deep as you can.
2. Place each block in a large bowl or polythene bag to collect any animals that might escape.
3. Put the two bowls or bags side-by-side on a table. Ask the group to study the soil structure and look for any organisms. They can use the knives to scrape away soil from the block. Help them identify the different types of organisms.
4. Get the participants to tip out the soil onto two large sheets. Ask them to carefully sort through it (children might like to help do this!). Get them to put the roots, stems, leaves, seeds and stones into separate piles. Put the organisms into the small bowls (use a spoon). Look carefully: some may be very small. Compare the amounts in the two soils. Ask the participants to spot burrows, holes, lumps of soil, and so on, that they think have been produced by living organisms. Compare them to the rest of the soil.
5. Ask the group to identify any of the animals they have found. Discuss their role in the soil.

Questions to stimulate discussion

- Is the "healthy" soil actually healthier? Why?
- What types of organisms have you found?
- What are they doing in the soil?
- What differences are there in the number and type of organisms in the two soils? Why do these differences occur?
- What has changed over time, and why? If many organisms have disappeared, the soil will not recover its productivity easily. Some soils have been so seriously degraded that it may never fully recover.

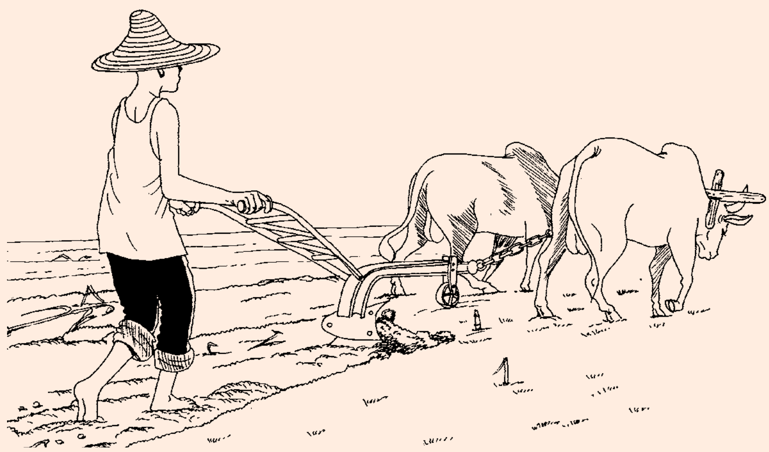


Figure 6.6. What happens to soil life and organic matter when I plough?

Exercise 6.3 Living with termites

In semi-arid areas, termites are important in forming the soil. But most farmers simply regard them as pests. Some termites can harm crops, particularly during droughts, but chemicals to control them are expensive, not always effective, and not good for your health nor the environment. This exercise looks at what termites do, how to manage them, and how to minimize the damage they cause using traditional means. This exercise is good for semi-arid areas where there are a lot of termites that feed on litter.

Before doing this exercise with farmer field school members, try out the practical exercises in advance.

Learning objectives

Observe termites foraging on different types of plant litter.

Understand how termites help form the soil.

Understand how termite galleries help water seep into the soil.

Observe that termites break up surface crusts.

Think of ways to manage termites.

Timing

Dry season and at the start of the rains.

Preparation

Find places with litter-feeding termites in and around fields. Try to find a place where termites are foraging on piles of crop residues (preferably on a slope). You can also set up piles as part of the exercise.

Get permission from the land owner to do an experiment on the land.

Duration

45 minutes for demonstrations.

Weekly visits for 4–6 weeks when experimenting with effects of termite activity.

Materials

Spade, watering can or large tin with fine holes punched in the bottom, water. ► *Exercise 10.4 Percolation* for measuring infiltration.

Steps

1. Ask the group to list good and bad characteristics of termites (e.g., attacking some crops, improving soil fertility, etc.).
2. Take the group to look at a place where termites are foraging on plant litter. Ask them to look at the effects the termites have on soils and plants. Help them to look for erosion, the soil texture (compared to surface soil elsewhere), and foraging tunnels.
3. Check plants growing on termite mounds. Compare them with plants elsewhere (they may be greener and healthier because they can get more nutrients).
4. Use a watering can or tin to show how termite-worked crop residues let a lot of water into the soil. If the location is on a gentle slope, pour water on the ground a little upslope from the residues, as if rainwater is flowing downhill into the pile.

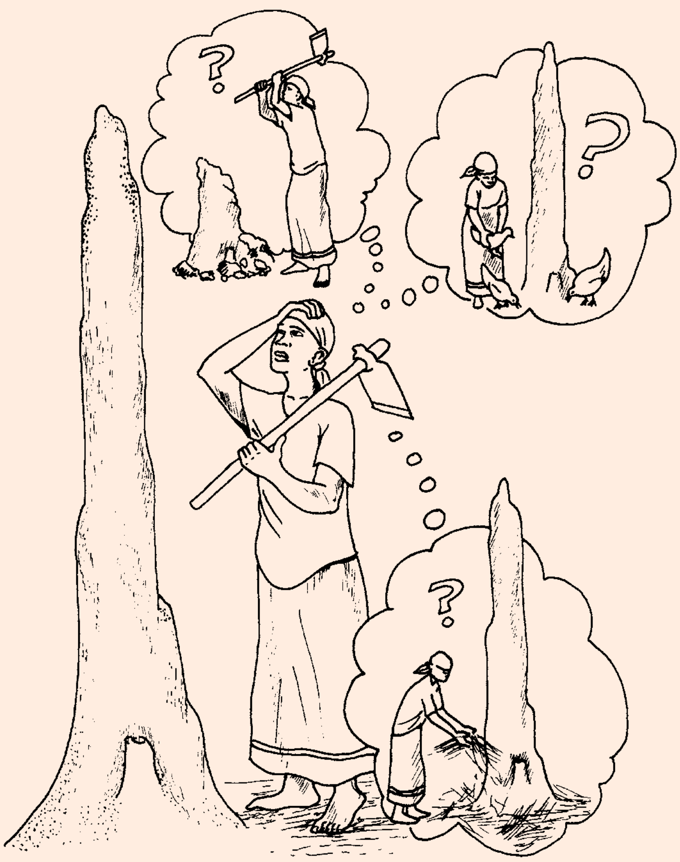


Figure 6.7. What to do with a termite mound?

5. Dig beneath where termites have been to show their foraging galleries. Point out that the size of the gallery depends on how long the termites have been working the area.
6. In a place where termites are working, dig (say) 10 planting pits, about 10 to 15 cm deep. In five of the pits, put a mixture of soil and vegetation; in the other five, just put in soil. Sow a few seeds of maize or another cereal in each pit. Water the pits, then put a layer of mulch over the five pits with the vegetation/soil mixture. Leave the other pits bare.
7. A week later (and again the following weeks is necessary), visit the pits again. Look for soil crusting, water seeping in, and the growth of crops and weeds.
8. Help the group think of ways to manage termites to reduce damage to crops.

Questions to stimulate discussion

- What can the termite mounds be used for? (bricks, pottery, ovens, etc.)
- Can termites themselves be used? (Collect them in bundles of litter to feed to chickens. They contain 44% fat and 36% protein.)
- Ask if local people eat "termite soil". Why? It is rich in minerals such as iron (against anaemia) and zinc (helps heal wounds), and is often regarded as a tonic. Termite soil also provides trace elements for plants (but it has little nitrogen or phosphorus).
- Do farmers plant crops on termite mounds? How do the crops benefit?
- Can termites be managed by "push/pull" strategies – using repellents to "push" them away from plants, and baits to "pull" them to other areas?
- Can ants be used to control termites?
- If we feed termites, will they do less damage to crops? The group could test if they can reduce termite attacks on crops by putting more maize stalks or other woody materials in or around fields to feed the termites and draw them away from the crops.
- Termites will take the food they need, so is it better to feed them?

Exercise 6.4 Earthworms in action

Earthworms are important to maintain the soil structure, especially under minimum or zero-tillage where their burrows are not destroyed by ploughing. Like termites, they increase the amount of water that seeps into the soil, and they move nutrients around. They are most abundant in fertile soils and work mainly in the topsoil. This exercise shows how earthworms improve soil structure and let water into the soil.

Steps

1. Ask the participants what they know about earthworms. What do the worms do? How do we know if there are lots of worms?
2. Ask what management practices affect the numbers of earthworms. What encourages more worms? What leads to fewer?
3. During a walk across a micro-catchment or a farm (► *Exercise 2.2 Transect walk*), count the number of earthworm casts per square metre in fields with different crops or under different types of management. Make a note of the numbers.
4. Dig up a block of soil using a spade. Break the block down by hand. Look for burrows, and count the earthworms. Make a note of how many you see.
5. Choose several areas with different sorts of mulch, and one place without a mulch cover. Count the number of earthworms at each place. Then check how quickly water seeps into the soil (► *Exercise 4.5*).

Mulch experiment

If you cannot find suitable areas with and without mulch, you can do an experiment:

1. Lay out plots with different types of mulches: high-quality (green manure), medium-quality (grass), and low-quality (stover or bagasse). Also have plots with mixtures of different types of mulches.
2. Several weeks later, measure how quickly the water seeps into the soil in each plot (► *Exercise 4.5*).
3. Dig out a block of soil from each plot and count the earthworms.

Compaction experiment

On heavy (clay) soils where soil compaction is a problem, you can test how mulch can overcome compaction by encouraging earthworms.

1. Measure how quickly water sinks into an area with undisturbed soil (► *Exercise 4.5*).
2. Tread on another part of the area to compact it (not too severely). Then measure how quickly water sinks in.
3. Cover the compacted area with a mixture of high and low quality mulch.
4. 2–4 weeks later, check the mulched area for earthworm casts. If you see some, measure how quickly water sinks in. Compare this with your records of the undisturbed area (step 1 above), and the compacted area (step 2).

Learning objectives

Observe how farm management affects the number of earthworms.

Understand how earthworms affect soil structure and water flow.

Understand how mulching can attract earthworms and help repair compacted soils.

Timing

Mid-wet season, or when earthworms are active (look for lots of casts of the surface).

Preparation

Find a place that has been mulched, and somewhere with no mulch.

Duration

1–2 hours for field survey.

30 minutes for demonstrations.

2–4 weeks for experiment.

Materials

2 sticks, each 1 metre long; spade, notepaper, pens.

To measure how quickly water seeps into the soil, ► *Exercise 4.5.*

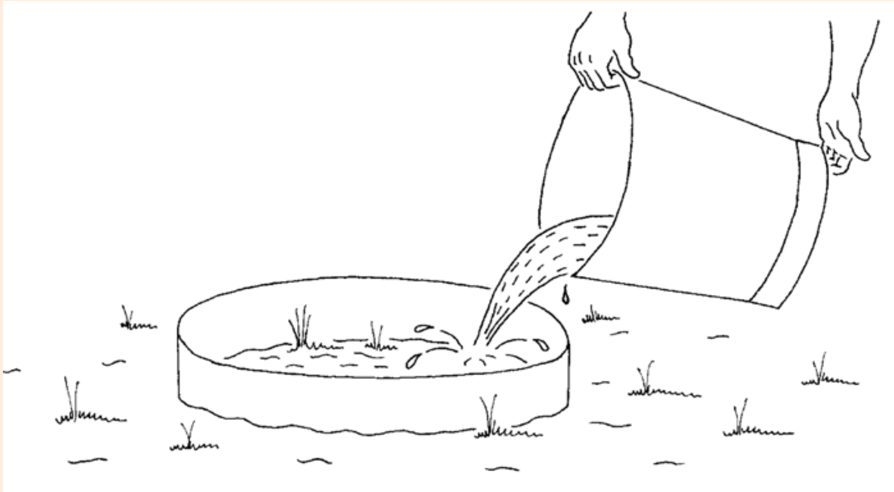


Figure 6.8. Measuring how quickly water sinks into the soil

Soil fertility experiment

1. Collect earthworm casts.
2. Plant seeds in two pots of soil: one with worm casts, and one without.
3. Several weeks later, check in which pot do the seeds grow best.

Questions to stimulate discussion

- Are earthworms good, neutral or bad for soils? Why do they think this?
- Do earthworms affect the soil, or do they just show whether the soil is healthy?
- What affects the number of earthworms (soil type, vegetation cover, farming practice)?
- What did you learn from the exercises? How can you manage your fields in a different way?

Exercise 6.5 Nematodes

This exercise enables farmers to see whether there are nematodes in the soil. It is not a good way to count how many there are or whether they are harmful – an expert is needed for that. Many nematodes are the farmer's friends, but some can harm crops.

Steps

1. Mix the soil thoroughly in water. Stir the muddy water, then pour it through a sieve to remove coarse material and large soil particles.
2. Let the soil settle, then pass the liquid through a tea strainer. Collect the water in a jar. Then filter again through a fine cotton cloth.
3. Take a small amount of the soil collected on the cloth, put it in a dish and add some water. Then look at it through a magnifying glass or microscope. Look for movements in the tiny soil particles. They are caused by nematodes moving. You may be able to see the nematodes themselves. They are commonly 0.5–1.5 mm in length, and shaped like a stretched-out letter S.

Questions to stimulate discussion

- How did we separate the nematodes from the soil?
- Do farmers know how to tell if nematodes are attacking their crops? What signs should they look for?
- What measures can farmers take to prevent nematode attack?

Learning objective

Be familiar with free-living (mainly beneficial) nematodes.

Timing

Middle of the wet season.

Preparation

–

Duration

Variable. Initial set up: 2 hours.

Materials

A handful of soil, coarse sieve (from a kitchen), fine sieve (0.4 mm holes – e.g., a mesh tea strainer), fine cotton cloth or filter paper, glasses or jars, glass dish or saucer, magnifying glass (or microscope if possible).

Exercise 6.6 Living organisms in the soil

Learning objectives

Be aware of the existence of living organisms in the soil.

Create sterile material (without any living things in it).

Timing

When discussing living organisms in the soil.

Preparation

Choose two soils: a "healthy soil" (forest, wood lot, productive grassland or field plot with lots of organic inputs), and a soil that farmers say is poor and unproductive.

Duration

Initial: 90 minutes.

Follow up: 5–7 days later.

Materials

A spoonful of each soil, three plastic bags (roughly 10–15 cm square; they must be strong enough to be steamed in a rice cooker without breaking); string, large rice cooker (steamer), about 400 g of cooked rice, 2 clean cups.

Adapted from

Settle (2001)

We have all seen mouldy bread, and most farmers have seen bacterial diseases of plants – though they may not know they are caused by bacteria. This exercise introduces the technique of simple sterile material used to grow both fungal and bacterial cultures. This might seem an elaborate way of demonstrating microbes, but by developing this technique, farmers and trainers will be in a position to multiply beneficial fungi at farmer level.

Steps

1. Put 75–100 g of cooked rice in each bag, and tie the bags with a piece of string.
2. Put the rice-filled bags into the rice steamer. Steam for 1 hour to kill all the organisms inside. As long as these bags stay sealed, they should remain sterile and nothing should grow on the cooked rice.
3. Put a spoonful of "healthy" soil into a cup and add some cooled, boiled water. Stir and let stand until the soil settles. Do the same for the other soil in a separate cup.
4. Open one bag and put in a tablespoon of the water from the "healthy" soil cup. Seal the bag up again quickly to avoid contamination, leaving some air in the bag (fungi and many bacteria need to breathe). Do the same for the other soil in a second bag. Tie the bags tightly shut, or seal them shut by melting the plastic over a candle.
5. For the third bag, just open it up to let some air in, then close it again, leaving some air in the bag. Then seal it in the same way as the other two bags. This bag is to show if there is any contamination apart from the soil water you have added.
6. Leave the bags in a dark spot at room temperature for several days, or until you see obvious microbial growth.
7. Check the bags again after 5–7 days. A slimy or soupy layer of many colours shows bacteria are growing. A layer of what looks like fine cotton fibres is fungus.

Questions to stimulate discussion

- What type of microbes developed on the rice?
- Can you see any differences among the three bags?
- What relationship do microbes have to organic matter?
- What other types of tests can you think of using this method?

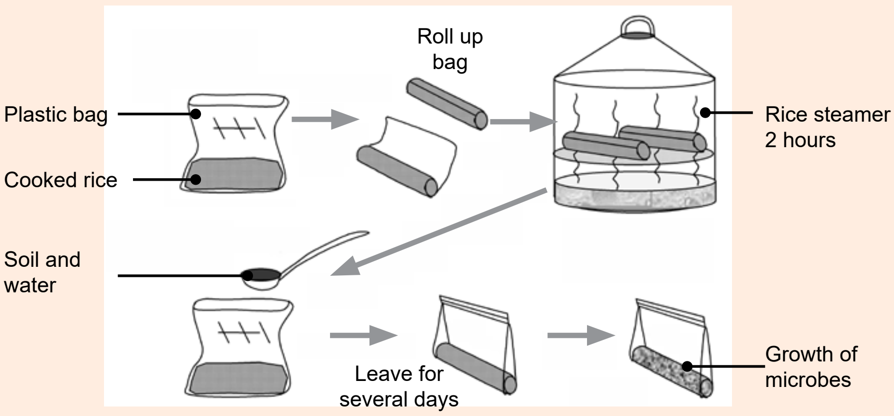


Figure 6.9. A test using boiled rice to check the health of soils

Exercise 6.7 Rhizobia in legumes

Rhizobia are very small, so it's not possible to see them without a microscope. But we can see the work they do to fix nitrogen in the nodules on the roots of legumes. This exercise shows farmers how.

Steps

1. Have farmers explain which legumes were chosen and where they were found.
2. Put the roots of the legume plants in the water and leave for 10 minutes for the soil to soak and soften. Gently wash the soil from the roots and lay the plants on a sheet of paper. Compare the roots with ► *Figure 6.10*.
3. Identify the main root and root branches. Check if there are any nodules (small, round or irregular knobs attached to the roots).
4. Count the total number of nodules in the roots of one plant. In general, each plant needs more than 10 active nodules to fix a lot of nitrogen.
5. Separate 10 nodules at random for each plant. Cut them in half using a sharp knife.
6. Look at the colour inside the nodules. Those that are whitish or beige are not fixing nitrogen. Brown or reddish nodules are active.

Questions to stimulate discussion

- Are these plants fixing nitrogen effectively?
- Are there a lot of nodules?
- What colour are they inside?

Notes

A ground cover legume can add as much nitrogen as a bag (50 kg) of urea per acre. However, peas, beans and groundnuts put much of the nitrogen they fix into their stems, leaves and beans. Harvesting the yield takes a lot of this nitrogen out of the field. If the farmer does not return the crop residues to the field, the soil may actually lose rather than gain nitrogen.

Nitrogen balance can be a difficult idea to explain. But farmers know how nitrogen affects the yield, and they know how much material can be used as mulch. ► *Module 7* looks at transfers of nutrients on a farm. It can help farmers understand such balances.

Learning objectives

Tell if legumes are taking nitrogen from the air.

Check if rhizobia (bacteria that fix nitrogen) are in the soil.

Understand how friendly microbes work.

Timing

When the legumes are fully grown, preferably flowering.

Preparation

Find where 5–10 well-known types of legumes are growing. Dig up one plant of each type, along with the soil it is growing in. Try not to damage the roots.

Duration

30 minutes to 1 hour.

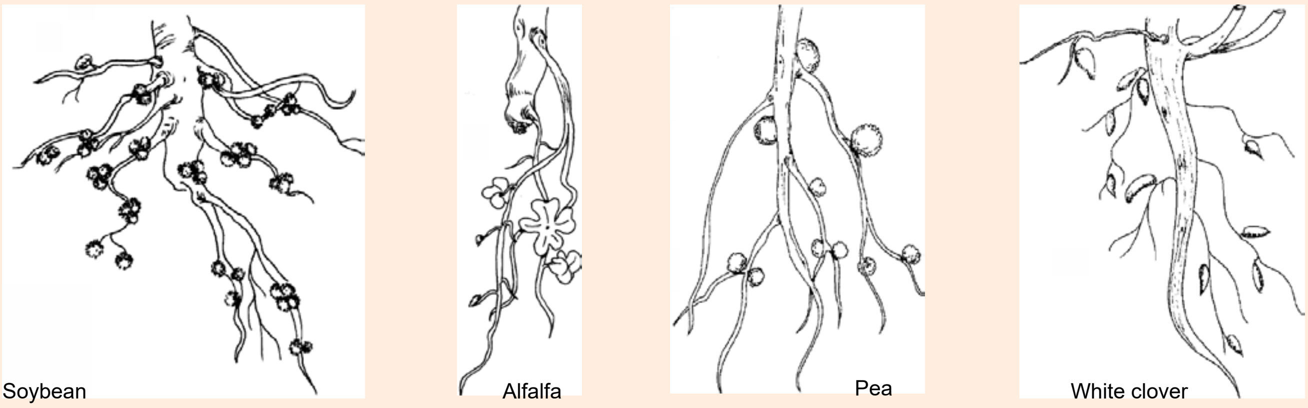
Materials

Small, sharp knife or razor blade; hoe, microscope, several bowls or buckets of water, large sheets of paper, marker pens.

Adapted from

FAO (2000), Barrios et al. (2001), and Life in the soil (CSIRO)

Figure 6.10. Root nodules of different types of leguminous plants



Exercise 6.8 Becoming a root doctor

Learning objectives

Look at roots to diagnose soil problems.

Timing

Any time when crops are in the main growth phase (e.g., after the maize plant has grown its 9th leaf). The exercise is most effective with maize or sorghum.

Preparation

Select two or more plots where maize or sorghum plants have been planted at the same time, but look clearly different.

Duration

1 hour.

Materials

Hoe, knife or trowel, ruler or tape measure.

Farmers are experts at watching the germination, growth and health of crops, and they know about organic manures, fertilizers, water availability, pests and diseases. But whether a crop grows and yields well depends on its roots. If the rooting conditions are bad, the plants will be stunted, regardless of how much fertilizer you apply. This exercise helps farmers use roots to diagnose the health of the soil.

Steps

1. Dig a pit about 20 cm away from a maize plant. Dig at least 30 cm deep, breaking through a hardpan if there is one. If possible, dig down until you reach the rocks that lie underneath the soil.
2. Carefully scrape away the side of the pit towards the plant to expose the roots. Try to damage the roots as little as possible.
3. Facilitate a discussion using the points and questions below using examples of healthy and unhealthy rooting patterns.

Questions to stimulate discussion

- How deep is the soil? Measure the depth down to the rocks underneath the soil. This is the **soil depth**.
- How deep are the roots? Measure the depth with the ruler or tape measure. This is the **rooting depth**.
- How have the roots developed? A healthy set of roots should be shaped like an upside-down bowl. The tap root should go deep into the soil, and there should be plenty of fine roots.
- Have any roots followed channels formed by earthworms, termites or old roots? (This is easy to see in conservation agriculture plots.)
- As a root grows from a tiny thread to several millimetres in diameter, it exerts a lot of pressure on the soil. That means that old root channels stay long after the root has rotted, and help air and water get into the soil. But they are destroyed by ploughing.
- Break open chunks of soil to show fine roots growing through the earth. Note that the soil has to have an open, airy structure to let roots develop. Compact or waterlogged soils don't contain air, so roots will die (just like an animal in an airtight box).
- Note that fine roots are very important for forming organic matter in soil. But they decompose fast when the soil is tilled. So some of the benefits of the last crop are lost in preparing for the next crop.
- Is there a hardpan? How can we tell? If the main roots hit a hardpan they will grow sideways. Beneath the hardpan, the soil is pale and has no roots because roots and organic material have not been down there for years. Measure the depth down to the hardpan. This is the **effective soil depth**. Make the following points:
    - Even if the topsoil is in good condition, heavy rain will fill up the soil above the hardpan until water eventually flows over the surface. That causes erosion and washes away plant foods.
    - When the surface layer dries out, there is no water stored deep down in the soil because it cannot get through the hardpan.

- A deeper rooting depth allows roots to grow down and fetch nitrogen and other nutrients they find there.

If there is a hardpan, then the farmers are cultivating only half the soil in the field. They must break up the hardpans with a hoe, pickaxe or chisel plough, or cultivate crops with taproots that can break the hardpan. ► *Module 8 Conservation agriculture.*

- In very infertile soils, farmers often sow crops in planting holes. Try digging a pit next to one of these holes. It will show that most of the roots are in the planting hole itself, because they cannot get any food in the surrounding soil. Digging the holes deeper than usual, and putting dung and fertilizer at the bottom can improve the crop's ability to withstand drought, since water also collects at the bottom of the hole. Top-dressing encourages surface roots to grow. Putting the top-dressing deeper encourages the roots to grow down, so can increase drought tolerance – as long as there is no hardpan.
- If the roots are stunted and yellow instead of healthy and white, there may be a problem with nematodes (in banana cropping systems).

► *Exercise 8.4 Looking at roots*

Exercise 6.9. Maximizing soil cover to increase biological activity

Learning objective

Demonstrate that crop residues or mulch can increase soil biological activity.

Timing

Towards the end of the rains, when the soils are still moist.

Preparation

Choose fields where crop residues or mulch have accumulated or been applied.

Duration

1 hour.

Materials

Spade or hoe, sheets of plastic or paper.

Adapted from

FAO (2000)

A major point of this module is to emphasize that a healthy soil contains a diverse living community, which maintains many key functions rather than simply an inert medium to support plant growth. Maintaining a healthy soil requires organic matter inputs to not only maintain organism activities but also soil physical and chemical properties. From a practical farming perspective inputs are more readily related to crop responses than to the biological processes and mechanisms. This exercise is useful in demonstrating that organic resource management improves soils and that the resulting diversity of organisms is indicative of a healthy soil. Conversely, it is important not to imply that most of the diverse groups of soil animals observed in this exercise are maintaining soil fertility rather than tracking it.

Steps

1. Ask the participants to look at the soil under the crop residues or mulch. Look for tunnels, channels and holes that have been created by living organisms.
2. Dig a square hole, 30 cm x 30 cm, and 30 cm deep, one layer of 5–10 cm at a time. Put each layer of soil onto a sheet of plastic or paper. Sort through soil and count the different organisms you find – earthworms, ants, termites, millipedes, centipedes, spiders, and so on.
3. Repeat steps 1 and 2 nearby where there are no crop residues or mulch.

Questions to stimulate discussion

- What living organisms can you see?
- How might they affect the soil (in terms of air, working organic matter into the soil, providing nutrients)?
- What would the soil be like if they were not here?

Module 7. Managing plant nutrients

Many farmers see their yields falling from year to year. Their soils have been severely depleted because they take nutrients out in the form of the harvest, but they don't put enough back again.

Every year, each hectare of Sub-Saharan Africa loses about 22 kg of nitrogen, 2.5 kg of phosphorus, and 15 kg of potassium. This has been going on for the last 30 years, on about 200 million ha of land – the size of Kenya, Tanzania, Uganda and Zimbabwe combined.

How can farmers maintain and increase yields? They need knowledge and skills to manage the nutrients they can get from within their farms and from outside. The best management practices depend on many factors: the needs of the crop, the soil's fertility and health, and agro-climatic conditions – as well as on farm size and other socio-economic factors.

This module will help farmers to improve nutrient management on their farms.

Learning objectives

After studying this module, you should be able to:

Describe the characteristics of fertile and productive soils.

Understand and assess crop nutrient problems.

Select organic and inorganic sources of nutrients, and use them to improve the crop.

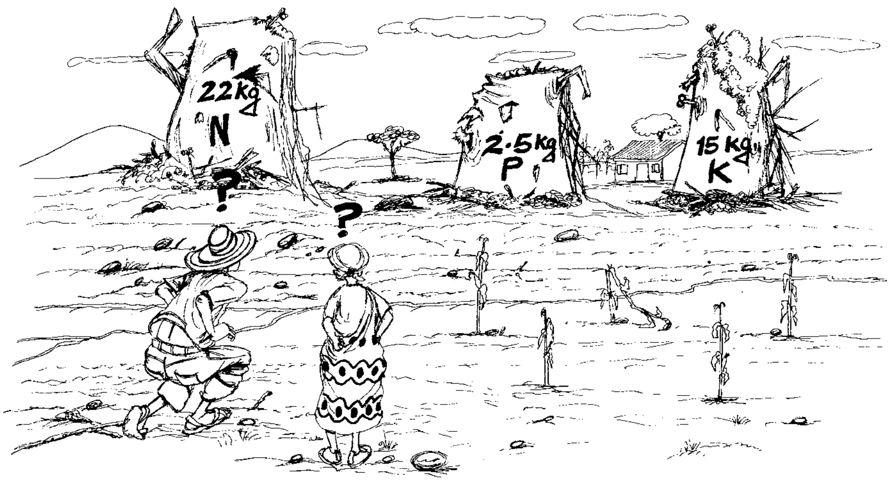


Figure 7.1. Africa's soils lose huge amounts of nutrients every year

Plant nutrients and soil fertility

Farmers and extension staff often think of soil fertility in terms of crop yields. They may not appreciate that fertility depends on several soil properties:

- The soil must be deep enough for roots to develop.
- It should be well-drained but able to hold enough moisture.
- It should not be too acid, or too alkaline.
- It should have an open structure so air can get to roots and living organisms in the soil.
- It should have lots of organisms to help keep it healthy.

The healthiest crops are produced on soils that have all these characteristics.

The fertility of the soil is influenced by its chemistry: the minerals it contains, whether it is acid or alkaline, how much salt is has, the amount of organic matter, and so on. The quality of the topsoil is very important. Soils that are low in organic matter will generally be low in nitrogen and phosphorus. Alkaline soils could suffer from phosphorus shortages.

Different crops like different types of soil. For example, tea likes acid soils and a lot of rain.

Most soils do not have everything the crop needs, so the yields are lower than they could be. If farmers take the harvest away and don't put anything back into the soil the fertility will go down.

This module focuses mainly on plant nutrients. But don't forget organic matter (► *Module 5 Using organic materials*) and moisture (► *Module 10 Managing rainwater*): they are just as important as nutrients. In fact, plants need them so they can reach and use nutrients.

What are plant nutrients?

Nutrients are plant food. They are essential minerals that plants must have to grow, be healthy and reproduce.

It is the same with humans. For example, iron is an important part of our blood. We need to eat food that contains iron, and if we don't, we become sick and may die if we don't get enough. We can get it by eating green vegetables, or things like beans, meat, liver, eggs, and nuts.

Plants need a lot of some types of nutrients: nitrogen (N), phosphorus (P) and potassium (K). These are sometimes called **primary nutrients**. These are the main ingredients of artificial fertilizers.

Plants need a moderate amount of other nutrients: calcium (Ca), magnesium (Mg) and sulphur (S). These are called **secondary nutrients**. Many soils that have been over-used do not have enough of these nutrients, especially if farmers have not put any organic matter back into the soil.

There is a third category, too: **trace elements** or **micronutrients**. Plants need only very small amounts of these. They include iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), molybdenum (Mo) and boron (B). Most of these trace elements come from the rocks beneath the soil and from organic matter. But if there are no trees or other deep-rooted plants that bring these nutrients to the surface, or if there is a hardpan that roots cannot grow through, trace elements may be in short supply. Most commercial fertilizers do not contain them.

What do plant nutrients do?

Each of these nutrients plays a certain role – or sometimes several roles. Together they allow the plant to grow healthy and strong. So soils must have nutrients in the right amounts. If one nutrient is missing, or if there is too much of another, the plant will not grow well or may not produce seed (► *Table 7.1* and *Figures 7.2 and 7.3*).

► *Exercise 7.1 Identifying crop nutrient deficiencies*

Table 7.1. What some nutrients do, and how to tell if they are missing

Nutrient	What it does	How to tell if it is missing	Where signs appear first
Nitrogen (N)	Needed for plant to grow and develop	Growth is stunted Older leaves go yellow, starting from tips	Older leaves
Phosphorus (P)	Helps roots to grow Helps flowering and development of seeds and fruit	Leaf veins and edges are purplish Roots do not grow well Deficiencies are common in early growth Plant matures late (though other things can cause this)	Older leaves
Potassium (K)	Keeps plant tissues healthy and working Increases root growth and improves drought tolerance Helps plants grow Produces grains rich in starch Increases protein content of plants Keeps the plant stiff and upright, reduces water loss and wilting Helps retard crop diseases and nematodes	Plant grows slowly and is stunted Edges of older leaves look yellow and scorched Stalks are weak Seeds are shrivelled	Older leaves
Sulphur (S)	Needed to make proteins, vitamins and oils	Leaves are mottled, yellowish-green Veins are yellowish Onions and cabbages (and other Brassicas) do not grow well	Younger leaves
Calcium (Ca)	Strengthens the plant tissues	Stems are weak Young leaves and roots grow short, crooked, wrinkled and bunched together Buds curl Plant does not grow much	Younger leaves
Magnesium (Mg)	Core element of chlorophyll (the green colouring of leaves) Helps plants use sunlight to make food Produces the energy to grow Enhances many enzyme actions	Whitish strips along veins Purplish colour on underside of lower leaves	Older leaves
Iron (Fe)	Helps plants use sunlight to make food	Pale green or yellow stripes between the veins on leaves	Younger leaves
Copper (Cu)	Helps the plant make food; makes the cell walls in a plant strong	Pale green leaves that wither easily, stunted growth, dieback	Younger leaves
Boron (B)	Helps make the cell walls in a plant strong	Stunting, barren ears, hollow stems and fruit, brittle, discoloured leaves	Younger leaves
Manganese (Mn)	Needed for the plant to make food	Pale leaves, pale stripes between veins on leaves. Stunting	Leaves

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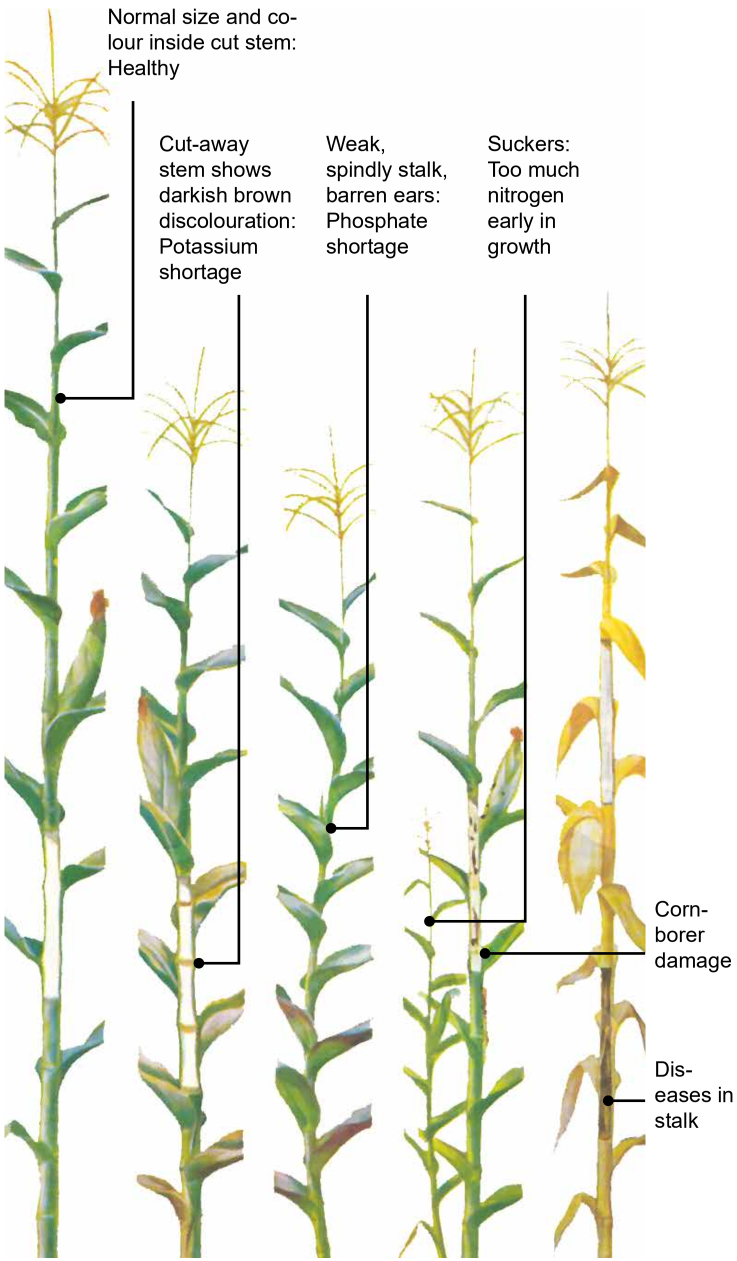


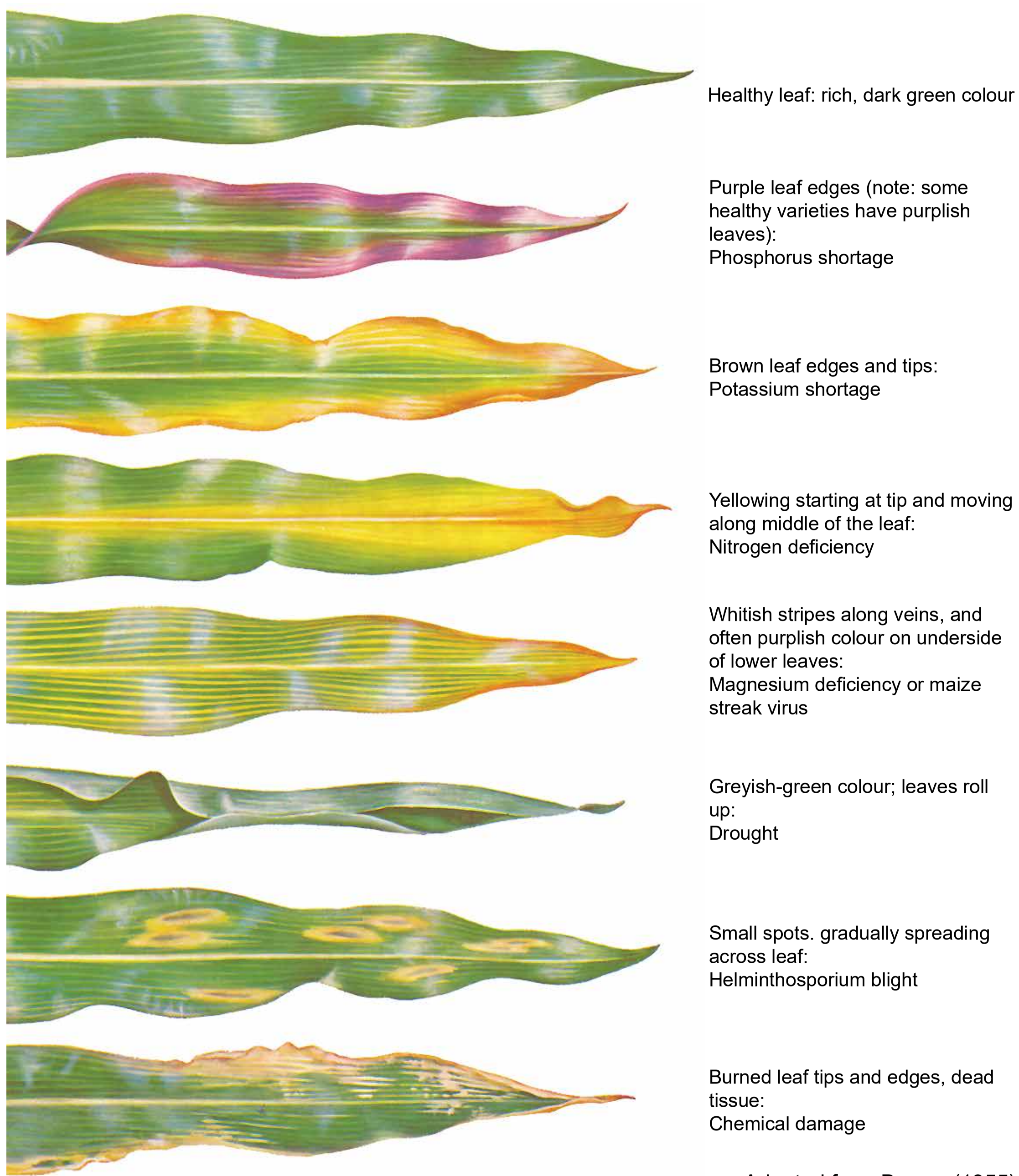


Figure 7.2. The maize doctor: plants and leaves

Adapted from Berger (1955)

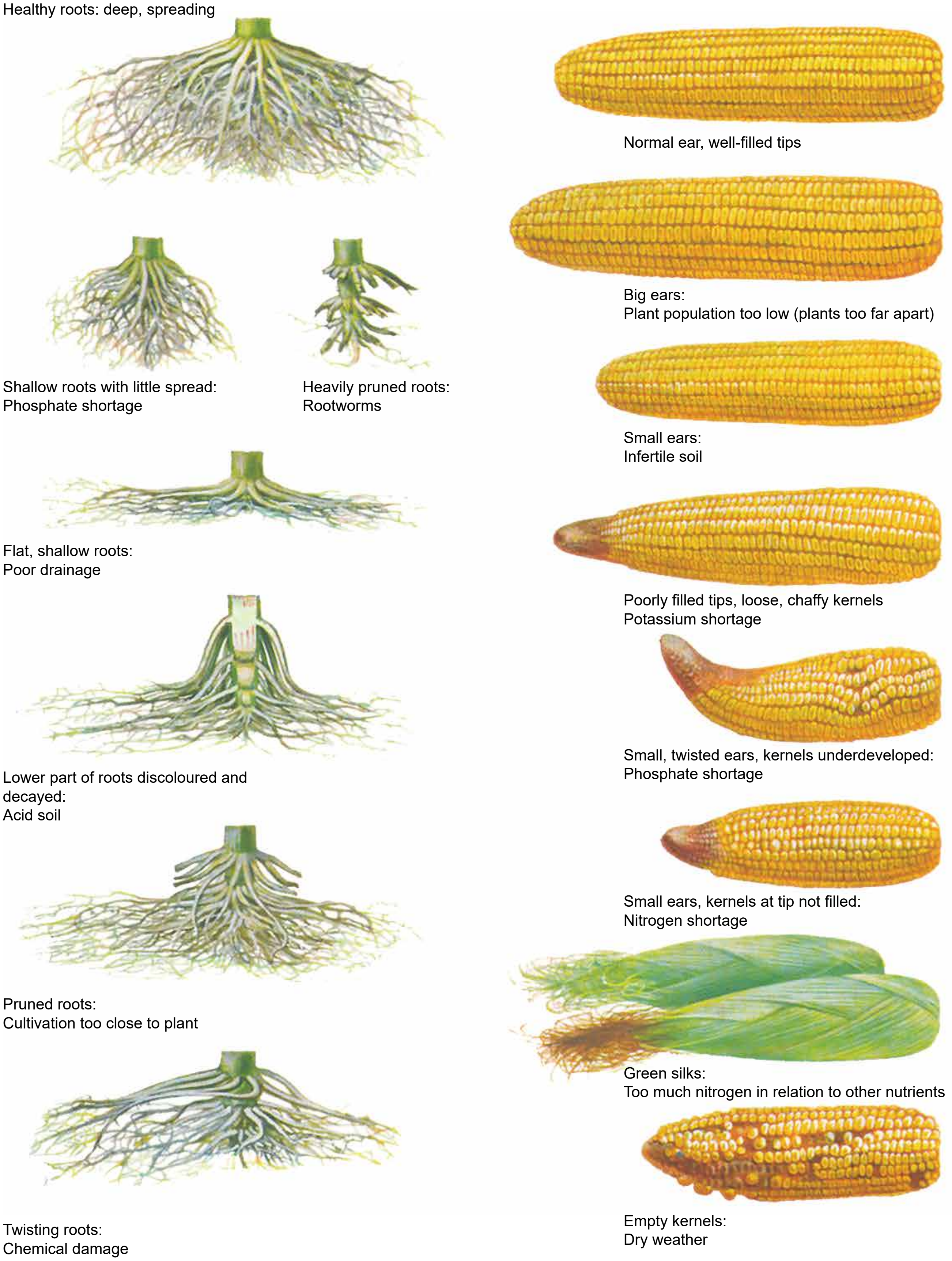


Figure 7.3. The maize doctor: roots and ears

Nutrient movements in the farm

Nutrients can be removed or added to soils in various ways (► *Figure 7.4*). Farmers take nutrients out of the field when they harvest the crop. The family eats the harvested food, and some of the nutrients go into pit latrines – so they are never returned to the field. People can also return nutrients to the fields, for example by grazing animals there, applying fertilizer, by planting legumes that fix nitrogen from the air. Nutrients can also be added when a flood deposits silt on a low-lying field.

One field may lose nutrients, even if the farm as a whole gains. Sometimes nutrients get concentrated in certain places – like in a well-cared-for vegetable garden. If you understand how the nutrients move around the farm, you can find ways to use them in a better way.

► *Exercise 7.2 Mapping resource flows*

► *Exercise 7.3 The bottle game: Nutrient movements*

Crop nutrient requirements

How many nutrients does a crop need? That depends on the crop, the soil and the climate. ► *Table 7.3* shows how much of each nutrient various crops take up from the soil. It also shows how much you should put back in if the soil is fertile. If the soil is infertile, you should put back more nutrients.

For **annual crops** on a **fertile soil**, work out using ► *Table 7.3* how much nitrogen (N) and potassium (K) the crop has taken out. You should put about half this amount back in, in the form of artificial or organic fertilizer.

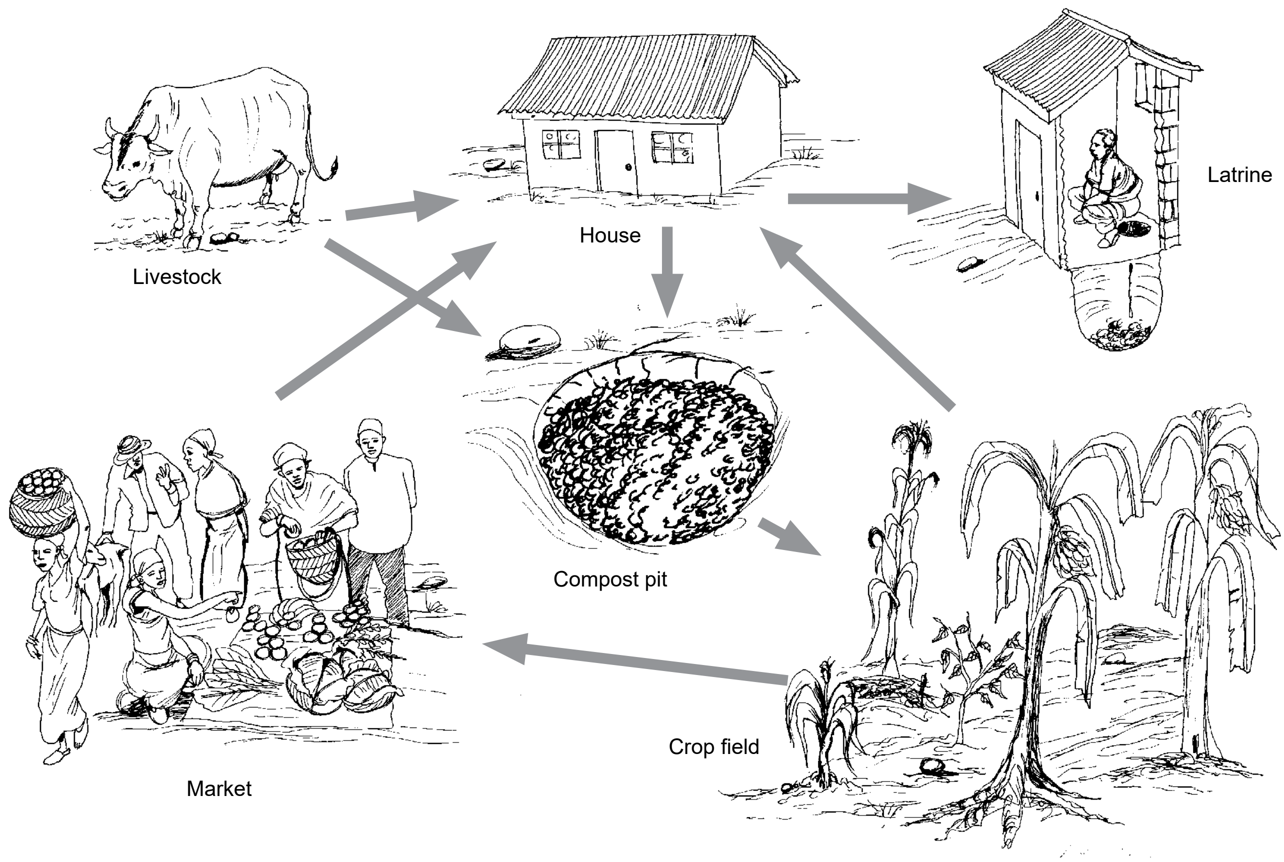


Figure 7.4. How nutrients circulate on the farm

Table 7.2. How many nutrients crops take out of the soil, and how much fertilizer to use

	If you get this yield (t/ha)…	…it takes this many kg of nutrients out of the soil (kg/ha)…			…and you should put at least this much back into a fertile soil (kg/ha)		
		N	P	K	N	P	K
Annual crops							
Sorghum	2	36	9	14	18	9	7
Maize	4	100	17	108	50	17	54
Rice	4	60	13	17	30	13	8.5
Wheat	3	70	13	50	35	13	25
Tobacco	2.5	50	7	104	25	7	52
Cotton	2	90	26	112	45	26	56
Cassava	25	125	13	125	63	13	63
Sweet potato	25	115	20	166	58	20	83
Groundnuts	1	50	13	12	25	13	6
Soybeans	2	125	13	33	63	13	17
Perennial crops							
Coffee	2	30	2.2	40	21	4.4	28
Tea	1	90	6.6	29	13	13	20
Banana	30	60	6.6	166	42	13	116

Also calculate how much phosphorus the crop has taken out. You should put this same amount of phosphorus back.

For an **infertile** soil, put back the full amount of nitrogen and potassium, and double the amount of phosphorus that the crop has taken out.

Perennial crops are different. On a **fertile** soil, put back 0.7 the amount of nitrogen and potassium that the crop removes, and double the amount of phosphorus. On an **infertile** soil, put back the full amount of nitrogen and potassium, and four times the amount of phosphorus.

Example: For a hectare of **maize** yielding **4 t/ha** in a **deficient** soil:

- **Nitrogen (N):** Removed at harvest = 100 kg/ha. Put this same amount back in (**100 kg/ha**).
- **Phosphorus (P):** Removed at harvest = 17 kg/ha. Put double this amount back in (**34 kg**).
- **Potassium (K):** Removed at harvest = 108 kg/ha. Put this same amount back in (**108 kg/ha**).

You can put these nutrients back into the soil in the form of organic materials (manure, crop residues, tree prunings) as well as artificial fertilizers (NPK).

How to assess soil nutrient status

To judge the amount and types of nutrients in the soil, you can check the following:

- **Soil colour.** Darker soils generally have more organic matter than lighter soils.

- **Indicator plants.** Farmers know what natural vegetation and weeds show whether a soil is fertile or not.
- **Crop growth and yield.** Check the colour of the leaves and the quality of the yield to see what nutrients are needed.
- **Chemical analysis.** You can get a lab to test your soil.

The following sections give details.

Indicator plants

Farmers often know that certain types of plants, trees and weeds grow well (or badly) on certain types of soil. They can tell by looking at these indicator plants whether the soil is sandy or clayey, dry or waterlogged, deep or shallow, and fertile or infertile. They know that if they see certain plants growing in a field that the soil is good (or bad) for certain types of crops. Using these indicator plants is a cheap and quick way of checking the soil fertility.

Indicator plants vary from place to place. Ask the farmer field school members what are good indicator plants for their area. Here are some guidelines for using them:

- **Know the area.** Local people often understand best the relations between the native vegetation, crops, soils and the weather.
- **Many are better than one.** A community of different types of plants is a better guide to soil conditions than just a single species.
- **Rare is better than common.** A particular type of plant that grows only in certain conditions is a better indicator than a common species that grows in lots of places.
- **Perennials are better than annuals.** Native perennial plants (plants that survive for many years, such as trees) are better indicators than annual species (which die off each year, like grasses).
- **Annuals show grazing pressure.** Checking the annual plants is a good way to tell whether an area is (too) heavily grazed.
- **Look at the colour of the leaves.** You can detect that particular nutrients (especially N, P and Mg) are deficient by looking for changes in the colour of leaves in the crop or in certain other types of plants, such as hemp and buckwheat (► *Figure 7.2*).

Crop growth and yield

While the crop is growing, you may be able to tell whether nutrients are short by looking at the leaves, grain and the plant as a whole (► *Figures 7.2* and *7.3*).

Different crops may show different signs of nutrient shortages. Be careful though, as certain pests and diseases can cause the same signs. In particular, maize streak virus is a common disease in maize. Magnesium deficiency looks the same, but is very rare. If the signs are noticed over a long period of time or in a large area with the same type of soil, nutrient problems are probably the cause.

Look also at the pod size, the amount of filled grains on the cob, and so on (also in ► *Figure 7.3*). But remember, weather and disease may also affect these. You should confirm your suspicions by checking in other ways (► *Exercise 7.4 Studying limiting nutrients*).

There may be enough nutrients in the soil, but plants may still be short of nutrients for other reasons:

- The initial growth conditions may make the plant weak and stunted.
- The roots may be restricted or may grow abnormally (perhaps because of pest or disease attacks, stony or compacted soil).
- The plant may mature too early or too late.
- The soil may be very acid (causing phosphorus deficiency).
- The soil may be waterlogged (causing nitrogen deficiency).

► *Exercise 7.4 Studying limiting nutrients*

► *Exercise 7.7 Using maize to test soils*

Chemical analysis

It is possible to do a simple chemical analysis of the soil in the field to assess soil organic matter. This can give an idea of the status of major nutrients: nitrogen, phosphorus and potassium.

You can also take a soil sample and send it to a laboratory for more accurate tests.

► *Exercise 5.1 Observing soil organic matter*

► *Exercise 5.2 Organic matter as glue*

Tackling nutrient problems

What action should you take when you have discovered that your soil has a nutrient problem?

You can add organic matter or artificial fertilizers. But first, you need to find out why your soil has a nutrient problem. And you should weigh the costs and benefits of adding nutrients.

Organic materials

Smallholder farmers may have organic materials at hand, but these materials differ in quality. ► *Table 7.4* shows how much nitrogen, phosphorus and potassium different organic materials contain.

High-quality materials (such as animal manures and green legumes) contain a lot of nutrients and decompose quickly. Poultry manure generally has a lot of nitrogen and phosphorus. Manure from goats and sheep is generally of higher quality than cattle manure.

Low-quality materials (such as maize stalks or manure from animals given poor feeds) are low in nutrients. Tough, woody materials such as maize stover decompose slowly. That means they keep nutrients in the soil, help form soil organic matter and improve the soil structure. But they provide nutrients only slowly to a growing crop as they decompose.

It is a good idea to use plant materials as fertilizer. But they have limitations:

- They generally have fewer nutrients than manures, so you need more to feed the crop.
- They are bulky and hard to transport.

Table 7.3. How many nutrients do organic materials contain?

Note: actual amounts may vary widely.

	1 kg of material contains this many grams of…			Notes
	N	P	K	
Crops[1]				
Maize grain (dry)	13.5	2.5	3.0	
Beans (dry)	34.3	3.9	17.2	
Kale (fresh)	5.3	0.6	4.5	
Plant materials				
Leguminous cover crops	35	2	20	Compete with crops for same land
Shrubs / tree prunings	20	1	15	Pruning and carrying are hard work
Crop residues	15	< 1	10	Often used as fuel, fodder or thatch rather than as fertilizer
Kitchen and agricultural wastes	10	0.1	10	Very low quantities produced
Animal manures				
Poultry	48	18	18	High quality, but little produced
Compost made from refuse	20	7	20	Takes a lot of work; little raw material available
Goat	24	7	14	Small quantities
Sheep	13	5	6	Small quantities
Cattle	13	2	15	Bulky and takes work to apply

Source: R. Delve, CIAT

- They may release nutrients slowly – sometimes too slowly to feed the crop.
- There may not be enough to use on all the fields.
- Farmers use them for other things, such as fuel, fodder or thatch.

► *Exercise 5.4 Sources of organic material*

► *Exercise 9.4 Different types of manure*

Managing organic materials

- If farmers plough their fields, it is best to incorporate organic materials into the soil (e.g., as green manures). If the materials are left on the surface, plants may not be able to reach the nutrients, and the nutrients may be washed away by rain.
- In conservation agriculture, on the other hand, soils are not ploughed (► *Module 8 Conservation agriculture*). Organic materials are left to decompose on the surface. Their nutrients are carried into the soil by earthworms or by rainwater.
- You can use low-quality materials such as maize stover in different ways: as mulch, by composting them with high-quality materials, or by chopping them into small bits and mixing them with inorganic fertilizers before working them into the soil. You can also leave these materials in the

Table 7.4. Extended list of crops and the nutrients they contain

	1 kg of material contains this many grams of…			
	Water	N*	P	K
Cereals (dry)				
Maize grain	130	13.5	2.5	3.0
Sorghum	100	18.2	4.0	3.6
Wheat	130	20.5	3.8	3.5
Beans (dry)				
Beans (shelled)	100	34.3	3.9	17.2
French beans	110	30.1	3.0	13.2
Lima beans	100	34.3	3.9	17.2
Soybeans	100	58.6	5.7	16.2
Fruit (fresh)				
Bananas	740	1.6	0.2	4.0
Oranges	870	1.5	0.1	1.8
Pawpaw	890	1.0	0.1	2.6
Watermelon	920	1.0	0.1	1.2
Vegetables (fresh)				
Cabbage, cauliflower	920	2.3	0.2	2.5
Carrots	880	1.6	0.4	3.2
Green pepper (chilli)	880	3.2	0.5	3.4
Irish potatoes	790	3.3	0.5	5.4
Kale	840	5.3	0.6	4.5
Onions	900	1.9	0.3	1.6
Peas	790	8.7	1.1	2.4
Pumpkins	920	1.6	0.4	3.4
Spinach	920	4.6	0.5	5.6
Sweet potatoes	720	2.4	0.6	0.6
Other crops				
Coffee cherries	750	0.8	0.8	5.0
Sugarcane	680	4.7	1.0	4.9
Tea (fresh)	600	0.6	0.8	0.8
Tobacco (fresh)	920	4.6	0.5	5.6
Fodder (dry)				
Beans (with shells/straw)	120	15.5	2.0	15.8
Hay (grass)	120	13.7	2.9	22.9
Maize cobs (shelled)	140	11.4	1.9	6.0
Maize stover (dry)	160	7.9	0.7	9.8
Fodder (fresh)				
Calliandra leaves	650	2.8	0.5	6.0
Banana stems	950	0.2	0.1	1.3
Coffee husks	150	0.3	2.2	19.6
Grass	850	2.6	0.5	3.9
Desmodium	750	4.0	0.1	1.0
Leucaena	700	12.0	0.1	1.2
Lucerne	840	6.6	0.4	4.8
Maize fodder	800	2.5	0.2	2.6
Maize stover (green)	650	3.9	0.3	4.1
Maize thinnings	870	1.6	0.1	1.7
Pumpkin leaves	930	5.0	1.0	4.4
Sweet potato vines	860	4.2	0.3	1.1
Weeds	850	2.4	0.3	2.3

Source: Adapted from data compiled by R. Delve, CIAT
Note: actual amounts may vary widely.
*High levels of nitrogen (N) mean that the crop contains a lot of protein, so is likely to make good livestock feed.

> **Box 7.1. Combining organic materials**
>
> *Adding rice straw (a low-quality organic material) as organic manure for a maize crop might seem like a good idea. But as the rice straw decomposes, microbes take nitrogen from the soil, starving the young maize plants of nitrogen.*
>
> *A green manure of Gliricidia, a tree legume, on the other hand, decomposes quickly. Too quickly for the maize to use. Its nutrients are washed away by the rain.*
>
> *Combining the rice straw and Gliricidia is the solution, researchers in Sri Lanka found. Together, they provide the right amounts of nitrogen at the right time, when the maize plants need it (P.T. Bandara and J.M. Anderson, unpublished data).*

field over the dry season to let termites work on them and improve the porosity of compacted soils. They decompose quickly when are ploughed under at the start of the next rains; this can lead to some nutrient losses.

- Woody stems and twigs do not make good compost because they decompose very slowly. Leave them on the soil surface to control erosion and help conserve moisture.
- If you have both high- and low-quality organic materials, mix them before applying them to the field, or compost them between the growing seasons.
- Mix plant and animal wastes to improve the quality of the organic matter.
- It is best to use both organic and inorganic fertilizers, rather than just one of them. This has several benefits:
- Organic matter improves the soil conditions so roots can grow and find the water and nutrients the plants need. Organic matter also contains secondary and trace nutrients that standard NPK fertilizers do not.
- You can use inorganic fertilizer to make up shortages of nutrients. For example animal manures may have enough phosphorus and potassium, but not enough nitrogen. You can make up this shortage by adding urea.
- Materials that are low in nitrogen (such as maize stover) can hold onto nitrogen released by high-quality materials (urea, manures). They then release the nitrogen slowly later in the season. That is good because it prevents the nitrogen from washing away. But it can starve the young crops of nitrogen. To avoid this, either add the organic materials well before planting, or add extra nitrogen just before planting.

See ► *Module 5. Using organic materials* for more on organic materials

Inorganic fertilizers

Organic fertilizers might not be enough to replace the nutrients that crops take out of the soil. Adding inorganic (artificial) fertilizers can make up this shortfall. This is true especially for soils that are infertile and low in nutrients or organic matter.

Benefits of using inorganic fertilizers

- Fertilizers can be applied precisely where and when they are needed.
- They release nutrients quickly, unlike some organic materials.
- You can apply the required amount of fertilizer at the right time during the crop's growth. That saves time and money, and avoids applying too much fertilizer at one time.
- It is possible to apply certain fertilizers (or a mix of fertilizers) to overcome specific nutrient needs – to meet a crop's needs, or to overcome certain deficiencies in the soil – you may need to take soil samples to a lab for analysis to find out which fertilizers to use.
- Inorganic fertilizers are less bulky than organic fertilizers, so are easier to carry and spread.

Inorganic fertilizers should not be used instead of organic matter. Rather, you can use them as well as organic matter to make sure the crop gets the food it needs and the soil structure is improved.

Challenges with using inorganic fertilizers

- In some places, inorganic fertilizers are very expensive or not available.
- Inorganic fertilizers may not be worth buying if yields or crop prices are low, or if other problems (drought, pests, diseases) keep yields low.
- The local fertilizer dealer may not have the best type of fertilizer for your soils or crops. Applying another type of fertilizer may have less effect.
- Farmer field schools can help farmers to understand the different types of fertilizer they need and how to use them. But farmers also need to build relations with dealers to make sure they can get the right fertilizers.
- Many farmers do not know how to use fertilizers properly. They may get poorer yields than they expected, or may even harm the crop. Bad experiences may make them wary of using fertilizers.
- It's dangerous to rely too much on inorganic fertilizers. If you don't use organic fertilizers too, the soil structure may get worse, the organic matter will go down, and more and more nutrients will be washed away.
- Applying some nitrogen fertilizers in the wrong way can make the soil acid.

Box 7.3. Selling fertilizers in small bags

Fertilizers come in big bags – usually 50 kg each. This is more than many farmers need, or can afford. The Farm Input Promotions Service in Kenya blends fertilizers to suit the local soil types, and repackages them into small bags – as small as 100 grams each. Demand for the mini-bags is high. Smallholder farmers and gardeners like them because they are cheap, easy to carry, and enough for a few plants.

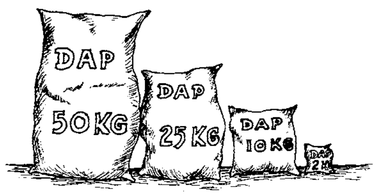


Figure 7.5. Small-scale farmers often cannot afford to buy big bags of fertilizer

Box 7.2. Fertilizer words

Fertilizer grade. The amount of nutrients in a fertilizer. The grade shows how many percent of the fertilizer is nitrogen (N), phosphorus (in the form of P_2O_5) and potassium (in the form of K_2O).

For example, 100 grams of a fertilizer labelled **15:10:5** contains

- 15 grams of N
- 10 grams of P_2O_5
- 5 grams of K_2O.

The rest of the 100 grams (70 grams) is known as **ballast**.

Check the fertilizer grade to decide which type of fertilizer to buy, and to work out how much fertilizer you need for a particular crop.

Straight fertilizers contain only one major plant nutrient (nitrogen or phosphorus or potassium).

- **Nitrogenous fertilizers** contain only (or mainly) nitrogen (N). Examples are urea, ammonium nitrate, CAN, calcium nitrate and SOA (► *Table 7.5* for the full names and what they contain).
- **Phosphate fertilizers** contain only (or mainly) phosphorus (P). The most common are SSP, TSP and rock phosphate.
- **Potassium (potash) fertilizers** contain only (or mainly) potassium (K). The most common are muriate of potash and sulphate of potash.
- **Compound fertilizers** contain at least two of these nutrients. They may be "complete" or "incomplete".
- **Complete fertilizers** contain all three major nutrients, N, P and K.
- **Incomplete fertilizers** contain only two of the three major nutrients.

The same fertilizer may have more than one name. For example, sulphate of ammonia (a nitrogenous fertilizer) is also known as "SOA" or "ammonium sulphate". Potassium fertilizers are often called "potash".

Table 7.5. Common fertilizers and the nutrients they contain

	1 kg of fertilizer contains this many grams of…			Considerations
	N	P	K	
Nitrogen fertilizers				
Urea	460	0	0	Excessive use in acid soils is damaging
Ammonium nitrate	340	0	0	Highly acidifying, recommended for alkaline soils, and paddy rice
CAN, calcium ammonium nitrate	260	0	0	Neutralizes acidifying effect. Recommended for use in acid soils. 1 kg also contains 100 g of calcium
CN, calcium nitrate	155	0	0	Useful in soils deficient in calcium. 1 kg also contains 190 g of calcium
SOA, ammonium sulphate	210	0	0	Good for sulphur-deficient soils. 1 kg also contains 180 g of sulphur
Phosphate fertilizers				
SSP, single superphosphate	0	180	0	
TSP, triple superphosphate	0	450	0	
Rock phosphate	0	320	0	Bulky, high transport costs and contains heavy metals
Potassium fertilizers				
Muriate of potash, potassium chloride	500			Not suitable for tobacco, fruits and vegetables.
Sulphate of potash, potassium sulphate	500			For tobacco, fruits and vegetables
Incomplete compound fertilizers				
MAP, mono-ammonium phosphate	110	520	0	Makes the soil acid
DAP, di-ammonium phosphate	180	460	0	Makes the soil acid
Complete compound fertilizers				
NPK Several formulations, e.g., 20:10:10	You can work out how many grams of each nutrient 1 kg fertilizer contains by multiplying these numbers by 10. So 1 kg of 20:10:10 fertilizer contains 200 g of nitrogen (N), 100 g of phosphorus (P) and 100 of potassium (K). The fertilizers can be bought ready-made, or made by mixing different straight fertilizers to suit certain crops and soils. Those with no K (e.g., 20:10:0) are still called NPK fertilizers.			

Managing inorganic fertilizers

Do's

- Make sure that the soil is moist enough before applying fertilizers.
- Apply fertilizers that are highly soluble (such as N and K fertilizers) in two or more split doses, when the crop needs them. This is especially important in well-drained soils in areas with high rainfall (because a single big dose of fertilizer would be washed away before the plants can use it).
- Apply slow-release fertilizers and phosphorus fertilizers near the plant roots so the crops can reach them.
- Store fertilizers in a cool, dry place.

Don'ts

- Don't apply fertilizers on top of soils that are being eroded – the fertilizer will be wasted! Apply soil conservation measures first, or bury the fertilizer in the planting hole so it is not washed away.
- Don't let fertilizer come into contact with seed or plants – it may "burn" them. Cover the fertilizer with soil before sowing the seeds (► *Exercise 7.5 Applying fertilizer as top-dressing*).
- Don't mix straight fertilizers that are not compatible. Some fertilizers should not be mixed because they react chemically with each other: that may mean nutrients escape or turn into a form that plants cannot use. Some fertilizer mixtures are dangerous – they can even explode! ► *Table 7.6* for which fertilizers it is safe to mix.

7

Should I use fertilizers?

Consider the following:

- **Soil type.** Different soils need different amounts and types of fertilizer. For example, nutrients are easily washed out of sandy soils, so you will need to apply fertilizers to them more often than on a clay soil.
- **Crop type.** Crops require different amounts of nutrients. For example, legumes fix their own nitrogen, so you will need to apply less nitrogen but reasonable quantities of phosphorus. Cereals need lots of nitrogen. Some crop varieties (such as maize hybrids) need more fertilizers than others (such as local maize varieties). Green vegetables require more potassium. Cabbages (and other Brassica crops) and onions need to get enough sulphur.
- **Climate.** In areas with a lot of rain, crops can probably get enough moisture, so nutrients are quite likely to limit their productivity. Adding fertilizer makes sense in such areas. In drier areas, there is not enough moisture for crops to use what nutrients are available – so there is no point in adding fertilizer unless you also irrigate.
- **Fertilizer prices.** If fertilizers are cheap, and you can get a good price for your crop, it makes sense to apply fertilizers. If you are close to a market and have easy transport, you can make better use of fertilizers than if you live in a remote area.
- **Crop management.** There is no point in applying fertilizers if you do not take care of your crop in other ways – planting at the right time, controlling weeds, pests and diseases, providing enough water, and so on.

Table 7.6. Fertilizer materials that it is safe or not safe to mix

		Nitrogen				Phosphate		Potassium		Mixed/compound				Other
		Ammonium nitrate, AN	Calcium ammonium nitrate, CAN	Calcium nitrate, CN	Ammonium sulphate, SOA	Single/triple superphosphate, SSP, TSP	Rock phosphate, RP	Potassium chloride, KCl, muriate of potash, MOP	Potassium sulphate	Monoammonium phosphate, MAP	Diammonium phosphate, DAP	NPK, NP, NK (based on ammonium nitrate)	NPK, NP, NK (urea based)	Lime, calcium carbonate
Nitrogen fertilizers	Urea	X	X	L	✓	X	✓	L	✓	✓	✓	X	✓	✓
Nitrogen fertilizers	Ammonium nitrate, AN		✓	L	L	L	✓	L	✓	✓	✓	L	X	✓
Nitrogen fertilizers	Calcium ammonium nitrate, CAN			L	L	L	✓	L	✓	✓	✓	L	X	✓
Nitrogen fertilizers	Calcium nitrate, CN				L	L	✓	L	L	L	L	L	L	✓
Nitrogen fertilizers	Ammonium sulphate, SOA					✓	✓	✓	✓	✓	✓	L	✓	✓
Phosphate fertilizers	Single/triple super-phosphate, SSP, TSP						✓	✓	✓	✓	L	L	L	L
Phosphate fertilizers	Rock phosphate, RP							✓	✓	✓	✓	✓	✓	✓
Potassium fertilizers	Potassium chloride, KCl, muriate of potash, MOP								✓	✓	✓	L	✓	✓
Potassium fertilizers	Potassium sulphate									✓	✓	✓	✓	✓
Mixed/compound fertilizers	Monoammonium phosphate, MAP										✓	✓	✓	✓
Mixed/compound fertilizers	Diammonium phosphate, DAP											✓	✓	✓
Mixed/compound fertilizers	NPK, NP, NK (based on ammonium nitrate)												X	✓
Mixed/compound fertilizers	NPK, NP, NK (urea based)													✓

✓	OK to mix
L	Limited compatibility. Mix only just before application
X	Do not mix

For example, do not mix urea (top line) with ammonium nitrate, calcium ammonium nitrate (CAN), SSP or TSP.
Adapted from: European Fertilizer Manufacturers' Association (2006).

When to apply fertilizers

Be sure to apply fertilizer when the crop needs it – not too early, and not too late. If you see the symptoms in ► *Figures 7.2* and *7.3*, it's probably already too late for this season!

Basal application

Also known as "starter application". This means applying the fertilizer at planting time. This is usually followed by a second application (side- or top-dressing) later in the growing season. Basal fertilizer is usually incorporated into the soil.

Side-dressing (or top dressing)

This means applying the fertilizer several weeks after the crop has germinated. An example is applying nitrogen fertilizer on maize when the plants are knee-high.

Split application

Applying small amounts of fertilizer several times during the growing season. Especially for nitrogen fertilizers, this reduces nutrient losses and gives you a better yield. It is also important on sandy soils.

How to apply fertilizers

You can apply fertilizer either on the surface or incorporate it in the soil. Incorporating it in the soil prevents it from washing away or evaporating into the air. Some fertilizers - such as ammonia and urea – are unstable and should always be incorporated into the soil.

There are several modes of application:

Figure 7.6. Broadcast application

Broadcast application

Spreading the fertilizer on the surface – for example, by throwing handfuls out while walking through the field. The fertilizer may then be incorporated into the soil (or not). Broadcasting is easy and can be combined with other operations. Starter fertilizer is often broadcast and then incorporated into the soil.

Figure 7.7. Band application

Band application

Placing fertilizer close to the plant roots so they can reach it easily. This is a good idea if you have a limited amount of a less-soluble fertilizer (such as phosphorus). But band application can be a lot of work.

Figure 7.8. Spot application

Spot application

Putting some fertilizer next to each plant (for example, in the planting hole before sowing). Don't put it too close to the seed as it can burn the seed. It is best to put fertilizers in the hole first, and cover them with soil before planting the seed. Some hand and animal planters are designed in such a way that both fertilizer and seed is deposited at the same time, few inches apart from each other.

Figure 7.9. Foliar application

Foliar sprays

Dissolving the fertilizer in water and spraying it on the leaves. This is used mainly to apply micronutrients to flowers, vegetables, and citrus. Fertilizers applied as sprays are highly diluted, so several applications will be needed. Fertilizers applied this way work quickly.

Fertigation

A combination of **ferti**lizing and irri**gation**: applying the fertilizer in the irrigation water, for example, in drip irrigation of fruit trees and flowers.

Box 7.4. Applying a fertilizer as top dressing

If you see your maize leaves going yellow near the central stem, your soil probably does not have enough nitrogen. You should add a nitrogen fertilizer such as CAN or urea fertilizer. One kilogram of urea contains about twice as much nitrogen as a kilogram of CAN, so urea may be better value for money.

After the first weeding, when the plants are about knee-high, apply 1 bottle top of urea (or 2 bottle tops of CAN) to the soil about 10 cm from the base of each plant. Covering the fertilizer with soil stops it from washing away.

► *Exercise 7.5 Applying fertilizer as top-dressing*

Soil amendments

You may be able to improve your soil by adding "amendments" to make it less acid and to improve the soil structure (► *Module 4 Knowing your soil*). The most common soil amendments are **lime** and **gypsum**.

Adding **lime** reduces the soil acidity. You can test the soil pH (a measure of acidity) to work out how much lime to add. You can add these materials:

- **Ground limestone** is one of the most effective and cheapest materials.
- **Dolomite limestone** also applies magnesium.
- **Wood ashes** and **bone meal** are also good sources of lime.

Lime is bulky and can be hard to find.

Try not to apply lime and fertilizers at the same time – leave several weeks in between. Lime controls aluminium toxicity (a problem on some soils). But it can cause some micronutrient deficiencies.

If your soil is acid (has a low pH), use CAN and CN fertilizer rather than urea, ammonium nitrate or ammonium sulphate (which can make the soil even more acid).

On alkaline soils (with a high pH), use acid-forming fertilizers such as ammonium sulphate, ammonium nitrate or urea, since they help correct alkalinity.

If your soil is saline (salty) or sodic (high in sodium), you can apply **gypsum** to get rid of the extra salt or sodium.

Combining organic and inorganic nutrient resources

The amount of organic matter in the soil drops rapidly after fallow land or forest is brought into cultivation, especially when the soil is tilled (► *Module 5 Using organic materials* and *Module 8 Conservation agriculture*). If the farmer tills the soil and does not put organic matter back into it, the soil properties will gradually get worse, until inorganic fertilizers have little effect on crop yields.

Unless the soil is in very good condition, farmers should apply both organic manures and inorganic fertilizers. Even a handful of compost or animal manure can improve the soil conditions and help plant growth. It is not clear whether it helps because of the additional nutrients, the better soil conditions, or (most likely) both these reasons.

The types of inorganic fertilizer and organic matter you should use, and the amount, vary from place to place, and from field to field (► *Box 7.5*).

How much fertilizer to apply?

In principle, answering this question is easy:

1. Work out how much of each of the major nutrients (N, P, K) your crop needs (► *Table 7.2*).
2. Work out how much of this you can put back into the soil using organic materials (► *Table 7.3* and *Exercise 7.6 Estimating the nutrients in crops, organic matter and artificial fertilizers*).
3. Then work out how much inorganic fertilizer, of which type, you need to make up the difference (► *Table 7.5*).
4. Use this amount as a guide for tests of various fertilizer amounts on your own fields (► *Exercise 7.4 Studying limiting nutrients*).

Remember that these calculations can be hard to do and give only a rough idea of how much of each type of organic and inorganic fertilizers to apply. Many things can affect the best combination: the soil type, location, climate, crop, climate, the timing of application, and so on. The actual amount varies from farm to farm, from field to field, and from season to season. The only way to find out is to do a test on your own fields (► *Module 3 Innovation and experiments*).

Box 7.5. Combining organic and inorganic fertilizers

Mr Ochwo and his wife grow crops on their farm in Kisoko, Tororo district, in Uganda. They learned about the idea of combining organic and inorganic fertilizers through a farmer field school supported by Africa 2000 Network Uganda.

The farmer field school tested various combinations of organic and inorganic fertilizers: legume residues, farmyard manure and DAP (an inorganic fertilizer that contains nitrogen and phosphorus). Mr Ochwo saw that by applying legume residues or manure, the amount of DAP could be halved, saving a lot of money. Since the couple started using a combination of organic and inorganic fertilizers, their maize yields have risen from 1 to 3 t/ha. Many of their neighbours have started copying them, and farmers from elsewhere have come to learn their technique. The Ochwos have started training people how to make compost. Demand for inorganic fertilizers has risen so much that the couple has decided to open a shop to sell them in the village.

Box 7.6. Experimenting with organic and inorganic fertilizers

Researchers and farmers applied farmyard manure, tithonia and fertilizers to four farms in Western Kenya, each with a different soil. On some of the farms the crops yielded much better than before, but on others, the yields stayed the same. The reason for this is not clear.

That means farmers should test their soils and various combinations of fertilizers before deciding what types to apply. And you should be especially careful about where you put fertilizer demonstrations. It may be best to have several demonstrations in different places rather than just one – which may not work because it happens to be on a particular soil type.

Exercise 7.1 Identifying crop nutrient deficiencies

Farmers can often tell what nutrients are missing from their soils by looking for tell-tale signs in their crops. Maize is a good crop to use because it is widely grown and shows many symptoms clearly.

Learning objective

Diagnose signs of nutrient deficiencies.

Distinguish nutrient deficiency symptoms from other problems.

Timing

This exercise can be done over different sessions, starting before the cropping season begins. It is best done along with ► *Exercise 7.4 Studying limiting nutrients*.

Preparation

–

Duration

2 hours.

Materials

Colour chart for nutrient deficiencies and pest/disease symptoms, large sheets of paper, marker pens.

Adapted from

FARM (1998) and SAFR (2005)

Steps

1. Explain the objective of the exercise. Ask farmers to discuss common crop problems they see in their fields that might be caused by nutrient deficiencies. List these on a big piece of paper, using the local names for the problems. Ask the participants to classify the problems according to how frequently they occur. Also ask them to explain the criteria they use to diagnose crop nutrient problems.
2. Ask the farmers whether any maize fields show the disorders they have listed. Choose several fields to visit.
3. Ask groups of 4–5 farmers to visit different fields and to return at an agreed time. Each group takes a copy of the list of common nutrient disorders of maize.
4. Each group describes and records any nutrient deficiency symptoms they notice in the maize. They should record the soil type, type of organic or inorganic fertilizer used, cropping history, and so on. They should also describe the topography (e.g., are deficiency symptoms more common on slopes or on flat land?) and other land uses. Ask the participants to compare the maize plants to the chart in ► *Figure 7.2* and take samples of the different disorders for all the farmer field school members to see.
5. When the groups come back together, ask each to present its findings. Invite them to discuss the possible causes of the disorders, and make a chart of the symptoms and probable causes. Try to distinguish nutrient deficiency signs from other problems such as lack of moisture, waterlogging, diseases and pest attacks.
6. Discuss ways to correct each of the problems.

Questions to stimulate discussion

- How does this symptom compare with the ones on the chart?
- Which symptoms are common in the middle of the growing season?
- Which symptoms mean the crop will yield poorly?
- What signs of pests and diseases did you see?
- How are the nutrient deficiency symptoms different from the pest or disease signs?
- What are the main nutrients deficiencies in the soil?
- What organic or inorganic fertilizers are needed in these fields?
- Do the symptoms depend on when the crop was planted?

Exercise 7.2 Mapping resource flows

Farmers move nutrients around their farms – in the form of grain, straw, manure, compost, fertilizer, fodder, and so on. This exercise helps them understand what they move where, and work out changes to improve crop yields.

Steps

1. Divide the farmers into groups of 4–5 people.
2. Ask each group to list the main types of land they use: grazing land, crop fields, gardens, livestock pens, woodland, etc.
3. Ask each group to draw a map showing one member's farm. This map should show all the fields, the crops grown last season in each, and the crops currently in each field. It should also show other land types, plus the farm family, house and livestock.
4. Each group then identifies nutrient-containing materials (grain, wood, manure, fertilizers, etc.) that move from one place to another. The group shows these movements by drawing different coloured arrows from one part of the diagram to another. For example, an arrow from a field to the house shows how maize grain moves. An arrow from the field to the goat pen shows that the animals are fed with crop residues. Do not forget to show flows such as grain going to the market, fertilizer coming from the market, how animal manure is used, and what happens to human waste. Label each arrow to show what it represents.
5. The farm's owner should estimate how many bags (or wheelbarrow-loads) of material is represented by each arrow. Write these estimates on the diagram.
6. Each group then analyses their resource flow map. How can the management be improved to make better use of the various resources?
7. Each group presents its findings to the whole group. Discuss refinements in the maps (allow other groups to query the nutrient flows). Ask the participants to identify ways to improve the management.
8. Encourage each participant to draw a similar map for his or her own farm, and present it at the next session. Encourage them to discuss with other family members at home.

Questions to stimulate discussion

- What resources can be found on the farm that might be used on the land? For example, coffee husks, rice husks, twigs, leaves, grass, nitrogen-fixing plants, ash from stoves, kitchen wastes.
- What resources do you get from grazing lands? From woodland?
- What resources do you get from the market?
- How were last season's crop produce and crop residues used?
- How to reduce the amount of nutrients that leave the farm? How can losses be reduced? How can more nutrients be brought in from outside? How might the nutrients be better used within the farm?
- What do we need to learn to improve the use of farm resources? For example, how to make compost, how to mix or rotate crops, which trees to plant?

Learning objectives

Visualize soil fertility management practices.

Analyse ways to manage farm resources.

Identify ways to improve how resources are managed.

Timing

Before the cropping season, and again during the cropping season (for comparison).

Preparation

–

Duration

1–2 hours.

Materials

Large sheets of paper, marker pens.

Adapted from

Hughes and Venema (2005) and FAO (2000)

Exercise 7.3 The bottle game: Nutrient movements

This game is an entertaining way to start discussions on resource management, the economic value of different resources, their nutrient contents, and inputs of organic and inorganic materials. If you are promoting organic farming, it is a good way to show the difference between nutrient cycling and restoration.

This exercise can easily be adapted to demonstrate nutrient recycling in crop–livestock systems (▶ *Module 9*).

Learning objectives

Understand the flows of nutrients in a farm.

Understand how these flows affect the balance of nutrients.

Understand the need to add nutrients from outside to maintain or restore productivity.

Timing

When discussing the management of plant nutrients.

Preparation

–

Duration

1 hour.

Materials

2 or 3 small plastic bottles (these represent crop and forage fields).

3 plastic cups (or bottles with the neck cut off) – one represents the livestock pen, one the market, and one the homestead. Make a small hole in the bottom of the livestock pen and homestead containers to represent leakage of nutrients (urine from cattle and human excreta down the latrine).

A pot containing about 2 litres of water. Don't use a jug, as this makes pouring too easy! This pot represents nutrient resources managed by the farmer (e.g., compost or manure).

Steps

1. Draw a circle on the ground, about a metre across. Explain that this represents the farm. Say that the group is going to see what happens to nutrients on the farm during a cropping season.
2. Ask the participants to put the bottles representing fields, livestock and homestead inside the circle. Put the bottle representing the market outside the circle. Explain what each represents.
3. Ask a volunteer to fill the "field" bottles from the pot. This shows that the farmer takes nutrients such as compost and manure to the fields at the start of the cropping season.
4. Explain that when maize is harvested, about half the nutrients it contains are in the grain, and half in the stover. Ask participants how much of the grain goes to the market, and how much is eaten by the farm family. Pour the equivalent amount of water into the "market" and "household" containers. Ask how much of the stover is given to livestock, and pour the corresponding amount of water into the "livestock" container. Pour the rest of the water back into the pot (this represents crop residues that are composted).
5. Explain that up to 20% of nutrients that livestock eat are converted into milk or meat, which can be consumed or sold. Pour the equivalent

Figure 7.10. The bottle game

amount of water from the "livestock" container into the "household" and "market" containers. The remaining water in the "livestock" container represents the nutrients in manure. Pour it back into the pot (manure is composted). Point out that a lot of nutrients are lost in the livestock urine (the hole in the bottom of the container).

6. Point out that part of the nutrients that go into the household is kitchen waste and can be composted. Pour the equivalent amount of water from the "household" container into the pot. The rest is lost – it goes into the latrine (through the hole in the bottom of the pot).
7. Check how much water is left in the pot at the end of the season.
8. Repeat steps 1–7 (the cropping cycle) several times until the water pot is empty. Repeat the exercise, trying to reduce spillage as much as possible (representing efficient and inefficient farmers).

Questions to stimulate discussion

- Why has the water been lost? Discuss that spillage represents losses during handling, nutrients in water running out of the circle (erosion) or soaking into the ground (leaching). Note that water leaking out of the homestead container represents the latrine: large amounts of nutrients are lost and not recoverable (every time you go to the latrine you throw money down the pit).
- What happens to urine leaking out of the homestead and livestock unit? How much is lost? Can it be recovered?
- How can we minimize losses from the cattle unit? ► *Module 9.*
- What can be done to bring nutrients into the farm? (Examples: planting nitrogen-fixing crops, applying livestock manure, using tree prunings, buying inorganic fertilizers.)
- How many nutrients are lost in the form of grain taken to the market? How can we replace these? ► *Exercise 7.6 Estimating the nutrients in crops, organic matter and artificial fertilizers.*

Exercise 7.4 Studying limiting nutrients

Learning objectives

Find out which nutrients limit crop production in a particular soil or field.

Understand the benefits of applying organic matter as well as inorganic fertilizer.

Learn the best method to apply fertilizer while planting maize.

Set up, monitor and evaluate demonstration plots.

Timing

During the cropping season.

Preparation

Find a 25 m x 25 m piece of land to use for the experiment. Things to consider:

The whole piece of land should have the same soil type – one typical of the farmer field school members' farms.

Crops grown in the area should show signs of nutrient deficiencies. The experiment will show how to overcome these.

The land should not be near hedges or trees (which may shade the crops or take nutrients and water), termite mounds or drainage from livestock pens.

Prepare the land using normal practices.

Duration

4 hours to set up the study.

Monitor the study at least once a week throughout the season.

This is one of the most important exercises for a farmer field school. It reveals which nutrients are limiting maize yields and shows the benefits of applying organic matter.

You can adapt this exercise to test other types of fertilizers or seed varieties.

Steps

1. Facilitate a discussion about the nutrient deficiency symptoms in the colour chart. Have the farmers seen these symptoms? How widespread are they? What fertilizers do they use?
2. Explain that this study enables them to understand which fertilizers they need, without having to send a soil sample to a laboratory.
3. Lay out plots 10 m and 5 m wide, long with 1 m paths between them (▶ *Figure 7.11*). Label each plot with the intended treatment.
4. Dig planting holes at a spacing of 75 cm between rows and 25 cm within rows. Apply the combinations of fertilizer to each plot as shown in ▶ *Figure 7.10*. Apply 10 kg of manure per planting hole in plots 5, 6, 7 and 8 only. Cover the fertilizers with a layer of soil, then sow one maize seed in each hole, and cover it with more soil (c *Box 7.7* for the correct application method).
5. Manage the plots in other ways as normal (e.g., weeding, pest and disease management).
6. As the maize plants grow, their leaves may turn yellow in the middle. This shows they are short of nitrogen. When the plants are about knee-high, weed the plots, then on half of each plot, apply 1 bottle top of urea around the base of each plant. Cover the urea with soil to stop rain from washing it away. Leave the other half of each plot without any urea.
7. Visit the plots regularly throughout the growing season. Measure the crop growth each time. Use agro-ecosystem analysis (▶ *Exercise 3.3*) to gather this information and to observe the weeds, pests, diseases and beneficial insects in the field. Regular monitoring is necessary throughout the season in case the yields are affected by the weather, pests or theft.
8. At harvest, carefully measure the yields from each of the subplots. Count the number of cobs, the weight of grain, and note the quality of the cobs from each subplot. Weigh the maize straw from each subplot too.
9. Discuss the results of the study and what the farmers have learned.

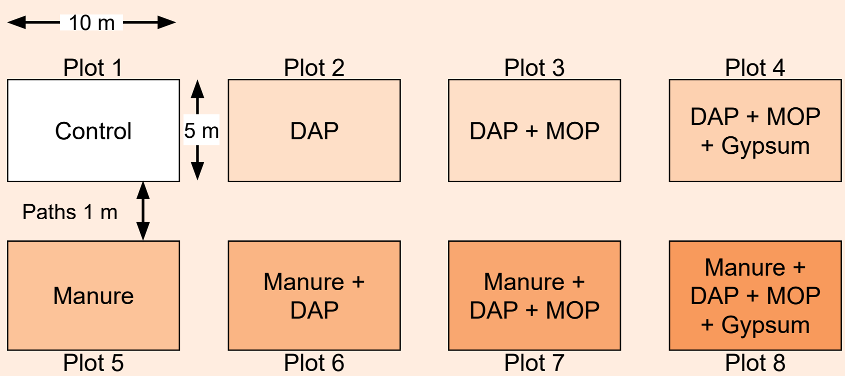


Figure 7.11. Layout of fertilizer experiment

Questions to stimulate discussion

- What have the farmers learned from the study?
- Do the results confirm the nutrient deficiencies the farmers have identified using the nutrient deficiency chart (► *Figure 7.2*)?
- How soon could the farmers see which combination of fertilizers was best? Were there differences between the treatments at germination time? When the seedlings were still small? In terms of growth, well before harvest?
- What effect did manure or compost have?
- How did the planting method differ from what farmers normally do?
- Did the best treatment overcome all the nutrient constraints?
- Is there a need to do another study next year? If so, should the treatments be changed?
- Can farmers run similar demonstrations on their own farms? What are the constraints and how can these be overcome?

Box 7.7. How to apply fertilizer at planting time

Avoid contact between fertilizer/compost manure and seed.

Fertilizer is best placed below and to one side of the seed.

When available, always apply fertilizer together with compost.

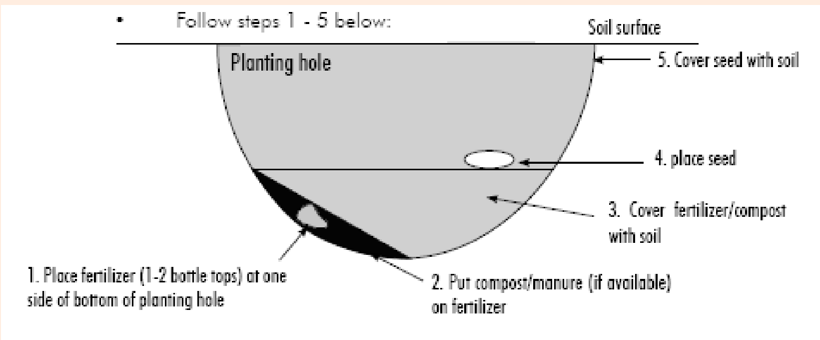


Figure 7.12 How to apply fertilizer when planting maize

Materials

Two packets of DAP fertilizer, each weighing 540 g.

Two packets each containing 540 g of DAP and 208 g of MOP fertilizer.

Two packets each containing 540 g of DAP, 208 g of MOP, and 313 g of gypsum.

Eight fertilizer packets each containing 270 g of urea (for use as top dressing).

Colour charts of nutrient deficiency symptoms in maize (► *Figure 7.2*).

Tape measure or measuring stick, maize seed (locally adapted variety); compost or manure; labels or notices that are resistant to water, rot and termites; waterproof marker pen.

Adapted from

FIPS Africa Ltd.

7

Exercise 7.5 Applying fertilizer as top-dressing

Learning objectives

Understand how rain can wash away fertilizer.

Know the best way to apply top dressings.

Timing

In the middle of the growing season, when top dressing is applied.

Preparation

Try out the exercise beforehand to make sure you know what you are doing.

Duration

30–45 minutes.

Materials

Watering can, or a large tin with small holes punched in bottom (check that it produces a spray like raindrops); 10–20 litres of water (free of dirt that might clog the sprinkler), a few handfuls of ground, sieved charcoal.

Top dressing with fertilizer is generally needed to boost the supply of nutrients when the crop is growing fast. Farmers often scatter urea, CAN or another fertilizer on top of the soil, or maybe scrape it only lightly into the soil. This exercise shows that unless the top dressing is placed correctly it may wash away, especially under maize, where rainwater runs down the stem.

This exercise uses charcoal to show what might happen to top-dressed fertilizer. Charcoal does not behave exactly the same way as fertilizer. Even so, the exercise is still a good way to help farmers understand how to apply fertilizer.

Steps

1. Find a field where maize is growing, and ask farmers to demonstrate how they usually apply top dressing.
2. Ask a volunteer to repeat the exercise using charcoal.
3. If their technique is good (► *Box 7.8*), give an example of a "poor" practice – leaving the fertilizer on the surface or covering it with just a thin layer of soil.
4. Water the area from as great a height as possible until the water starts running off. Observe what happens to the charcoal. Or you can wait until it next rains, then come back to check what has happened to the charcoal.

Questions to stimulate discussion

- Are there any signs of erosion? For example, silty fans between the rows, exposed prop roots of maize planted on ridges.
- How do the crop plants affect the rainwater hitting the ground? Do they protect the ground, or do they channel the flow of water? Maize and sorghum leaves conduct direct water down the stem, washing soil away from the base of the stem and exposing the prop roots.
- Has the charcoal been exposed or washed away? How can this be prevented?

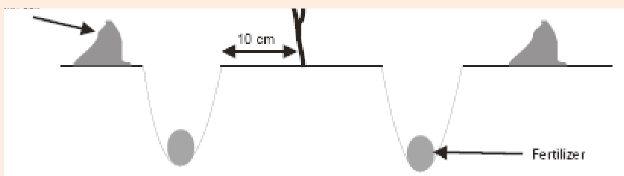
Box 7.8. How to apply fertilizer as a top dressing

If maize leaves turn yellow in the middle, your soil is probably short of nitrogen. You should add nitrogen fertilizer.

Use CAN or urea fertilizer (urea is about half the price of CAN per kilogram of nitrogen).

After the first weeding, when the plants are about knee-high, apply 1 bottletop of urea or 2 bottletops of CAN in a circle around the plant, about 10 cm away from the stem.

Cover the fertilizer with soil so the rain does not wash it away.



Exercise 7.6 Estimating the nutrients in crops, organic matter and artificial fertilizers

How many nutrients do various artificial fertilizers contain? How much compost or animal manure contain the same amount? And how many nutrients are taken out of the soil when the crop is harvested? This exercise helps farmers work this out. That will help them understand the value of different types of farm resources.

Learning objectives

Understand the nutrient contents of organic and inorganic fertilizers and crops.

Quantify nutrient contents using local weights and measures.

Express nutrient contents in fertilizer equivalents.

Estimate the amount of fertilizer needed to balance the nutrients taken out when crops are harvested.

Timing

When the various items to be measured are available.

Preparation

Find out what standard measures are used (e.g., 50 or 90 kg sack). Estimate the weights of loads such as a cartload of manure.

Duration

3 hours.

Materials

Large scales to weigh at least 25 kg; small scales to weigh up to 5 kg; local measures (e.g., in Kenya, a Kimbo tin, Debe can, wheelbarrow, etc.).

Items to weigh that contain nutrients: green manure, kitchen waste, different types of livestock manure, compost, fresh kale, dry maize grain, dry beans.

Steps

1. Weigh standard units of materials: a bag of maize, a tin of beans, etc. For large volumes (such as a wheelbarrow of manure), calculate how much they weigh by measuring part of the load and multiplying. If necessary, make several measurements to allow for variability, and then calculate the average.
2. Look up in ► *Table 7.4* how many nutrients (N, P and K) there are in 1 kg of various common crops. Calculate how much of each nutrient there is in the standard measure for that crop.
3. Look up in ► *Table 7.3* how many nutrients there are in 1 kg of different types of compost and manure. Calculate how much of each nutrient there is in a wheelbarrow full of each type of material.
4. Use ► *Table 7.6* to look up the nutrient contents of fertilizers that are used locally. Calculate how much fertilizer is needed to provide the same amount of fertilizer in the common crops, and in different types of compost and manure.
5. Facilitate a discussion about what participants have learned.

Questions to stimulate discussion

- Do these estimates give you a better understanding of managing resources?
- As a general rule, the market value of a product depends on how many nutrients it contains. For example, cassava contains less nutrients than maize, which in turn contains less than beans, which in turn contain less than meat and milk. A sack of beans contains 2.3 times more nitrogen, 1.4 times more phosphorus, and 5.1 times more potassium, than a sack of maize. So it is more expensive.

Exercise 7.7 Using maize to test soils

Learning objectives

Compare three soils by observing the growth of plants.

Timing

When water is available to water the pots.

Preparation

Identify three different soil types to test. The soils should be as different as possible.

Duration

Initial set up: 90 minutes. Follow up observations each day.

Materials

3 buckets, 12 pots, 40–50 seedlings of maize (or another crop grown in your area), large sheets of paper, marker pens.

Adapted from

Settle (2001)

This is an experiment to see how well maize grows in three different soils. You will need three different soil types from your area. For example, (1) a poor, sandy soil (perhaps from beside a road), (2) a soil from a typical field, and (3) a soil rich in organic matter (perhaps from a garden).

The exercise uses maize plants to show the differences between the soils. You can use a different crop if you want – beans, rice, tomatoes, or the major crop in your area. Don't use a weed, as weeds often grow well even in poor soils.

Be sure to use transplanted seedlings, and not planted seeds, as seeds carry with them an initial store of nutrients.

Steps

1. Collect a bucketful of each type of soil. Fill 4 pots with each type of soil.
2. Plant 3 or 4 seedlings in each pot. Do not add any fertilizer.
3. Put the pots in a safe place with good light. Water them every day (or when needed).
4. Every day, check the plant height, its colour, the number of shoots (if appropriate), and so on. Record this information in a notebook.
5. After 2 weeks, take several plants out of their pots and look at the roots. Check the number of roots, their colour and size.
6. Write your findings on a big sheet of paper and report back to the farmer field school group. Discuss the reasons for what you have observed.

Questions to stimulate discussion

- What aspects of plant growth did the soil type affect most? Height, colour, number of shoots, etc?
- If you used several crops, which showed the soil health and problems best?
- Compare the results of this experiment with your other experiments on the same soils. What can you conclude?

Notes

If you use sand from a building site as one of your soils, wash it first to get rid of any chemicals.

You may wish to try several different crops to see which are the best indicators of soil health.

Module 8. Conservation agriculture

Conservation agriculture is a way of farming that combats erosion, and that conserves and builds soil fertility. It avoids ploughing or hoeing in order to maintain the soil structure and conserve water. It keeps a cover of vegetation or mulch on the soil surface to protect it and hinder weeds. It includes crop mixtures and rotations to control weeds and pests.

This module shows you how to help farmers try out conservation agriculture methods and compare them with their usual practices so they can decide whether they want to take up this different way of farming. It shows how conservation agriculture can help them save money and effort, increase the soil fertility and improve crop production.

It can be hard to convince farmers to even consider trying out no-tillage practices. Many farmers are convinced of the "need" to plough to produce a good seedbed and "clean" fields. You should first introduce them to the idea of conservation agriculture and help them test it in a few study plots. You can then help them to adapt the new conservation agriculture practices to suit the local situation, and to monitor the effects on soil and crop health. After 2–3 years the improvements in the soil should lead to substantial improvements in farm productivity and sustainability.

The benefits of conservation agriculture take time to be seen. The first year should mean less work at first (no ploughing) and more timely planting (no need to wait till the fields are ploughed). But it may mean more work for weeding. The yields may not go up in the first year. The soil structure takes time to improve, and it takes time to build up the organic matter in the soil.

Farmers may lose interest if they do not see immediate improvements in yield. The facilitator should try to keep them interested by encouraging them to observe how the natural ecosystem is being restored – in terms of pest control, soil moisture, erosion control, soil life and health, etc.

Conservation agriculture includes many management practices: reduced tillage, direct seeding, weed management, cover crops, rotations, and the use of unfamiliar equipment. This module is not a detailed guide of conservation agriculture. Rather, it gives you entry points and practical exercises you can use to help farmers study this approach to farming.

You can find more information about conservation agriculture in IIRR and ACT (2005).

You will also need to find sources of cover crop seeds and the tools and equipment needed for conservation agriculture in the local area.

Learning objectives

After studying this module, you should be able to:

Help farmers try new ways of growing crops without ploughing.

Introduce conservation agriculture practices to prevent soil degradation and improve farm productivity.

Show how conservation agriculture practices help capture rainwater and hold it in the soil, increase the amount of organic matter and life in the soil, and tap nutrients better by rotating crops.

Initial discussion

The first step is to start a discussion with farmers about the changes in farming since their parents' or grandparents' time. For example:

- Have you noticed that every year it is more difficult to work your soil? And even if you work hard, your crop yields are less than last year.
- What about the older farmers in the village? Is it true what they say, that things used to be easier?
- What about the climate? Is there less rain than there used to be, or does it disappear faster?
- What are we doing to our soils through cultivating year after year?

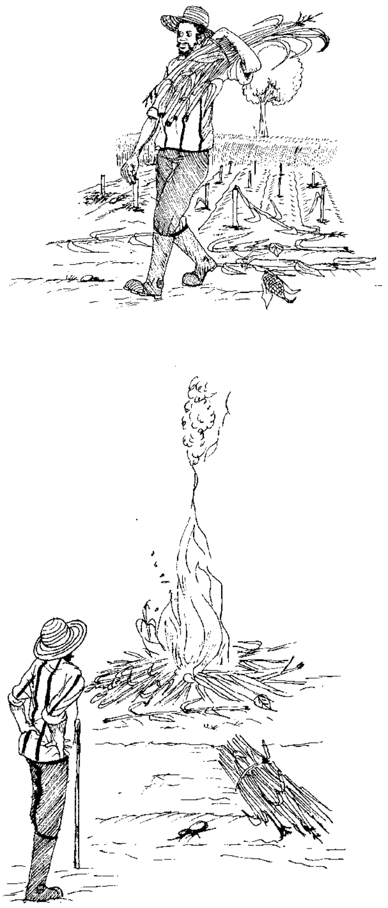


Figure 8.1. Removing crop residue from the field, and burning crop residue: both are a waste of valuable material, and harm the soil

Box 8.1. Conventional farming

Many farmers grow commercial cash crops, such as maize, groundnuts, cotton, coffee as pure stands. If they can, they use improved varieties and apply fertilizer and pesticides in the hope of increasing their yields.

What farmers do varies from place to place. But here is a general picture:

First, farmers burn the crop residues and surface vegetation, mainly to get rid of pests and weeds, and to make land preparation easier. They spend a lot of time tilling the land, either with a hoe or by ploughing. In many places, land preparation takes more work than it used to. Today's farmers may farm a smaller area or need more oxen or donkeys to pull the plough than their grandparents did. The animals may be weak because they do not get enough fodder during the dry season.

When the fields are finally ready, and rains can easily wash the bare, loose topsoil away, taking with it fertilizer and newly planted seeds. A hard layer in the soil, caused by ploughing, stops rainwater from sinking in the soil. Weeds grow well because it takes a long time for the crop to start growing and cover the soil. Because there is only one crop, weeds and pests are a problem. Controlling weeds is difficult because many people have gone to look for work in the towns, or are too sick (with malaria or HIV/AIDS) to help in the fields.

At harvest time, yields may be very low: the soil is infertile, the crops cannot get enough water, the field is full of weeds, and pests and diseases attack the crop. Although the farmers try hard to grow healthy crops, they cannot grow enough to feed their families.

Why conservation agriculture?

Conservation agriculture has many advantages over conventional farming:

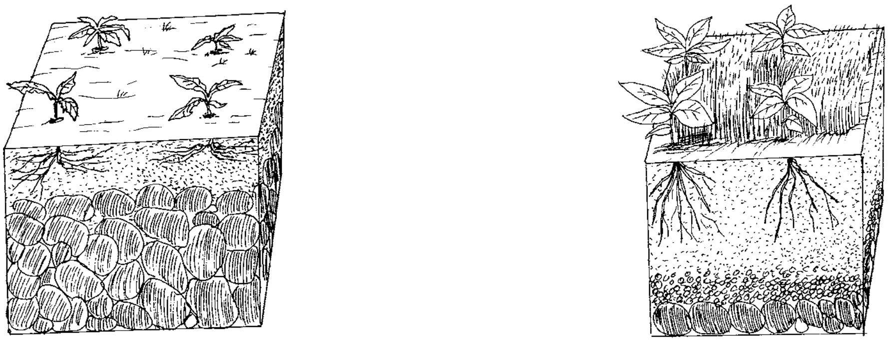
- It produces higher yields and more income.
- It takes less work.
- It controls soil erosion.
- It uses fewer pesticides and fertilizers.
- It uses soil moisture effectively, so crops survive dry spells better.
- It reduces production costs.
- It increases the lifespan of machinery and equipment.
- It allows marginal areas to be put into production.

How ploughing damages soil

What causes the situation described in ▶ *Box 8.1*? It is ploughing, harrowing and burning – all common practices – that cause the problems. These practices work in temperate regions because they help the soil to warm up quickly in springtime and facilitate germination and root development. But they are less suitable for tropical and sub-tropical areas.

In the tropics, ploughing and burning may give higher yields for a few years. But in the long term, they lead to the problems described in *Box 8.1*.

The soil is an ecosystem. It has living organisms such as earthworms, termites, insects, bacteria and plant roots, all interacting with each other and modifying the soil (▶ *Module 6 Encouraging soil life*). Plant roots need water



Like this? (conventional farming)

Or like this? (conservation agriculture)

Figure 8.2. How would you like your soil to be?

and air, but above all they need nutrients to live and grow. So do most other soil organisms. Ploughing (and hoeing) the soil affects them in many ways:

Ploughing turns over the topsoil and brings in air. This is good for the micro-organisms that decompose plant roots and crop residues. The microbes multiply rapidly, using up the nutrients that plant roots could have used. That is why crop seedlings sometimes look yellow: there is a temporary shortage of nutrients. When the microbes die, the nutrients become available to the plants. But then it may be too late: the seedlings will be weak unless they have received some extra nutrients in the form of fertilizer, manure or compost.

Ploughing breaks down the soil's structure. By making a fine seedbed, they get rid of vital air spaces in the soil. Compare the soil to a house, which has useful spaces - the rooms where people sleep or eat. If you destroy the house, you lose those spaces or rooms. The bigger spaces in the soil are the pores and channels created by roots, worms and beetles. They hold air, and let water through. The smaller pores hold water which plants roots need. Ploughing destroys all these spaces, so there is no more air or water that plants need. In hotter climates, turning the soil allows it to dry out even more.

Ploughing stops water from sinking into the soil. When it rains on ploughed or hoed soils, the big pores and channels made by animals and roots are no longer there to guide rainwater into the soil. Heavy raindrops batter the soil surface, breaking off tiny particles of soil that quickly block up holes in the surface. Instead of entering the soil, water runs away down slope. It eventually finds its way into streams and rivers, where crops cannot use it. Worse still, this water carries valuable topsoil with it, polluting rivers, causing floods in low-lying areas, and clogs reservoirs and irrigation canals with silt.

Ploughing can make weed problems worse. Farmers think they are getting rid of weeds when they plough and hoe. But they may spread weed seeds or rhizomes (underground stems that can regrow). They may bring buried seeds back to the surface where they can germinate. So ploughing and hoeing may actually increase the number of weeds in the field.

► *Exercise 8.1 The umbrella*

► *Exercise 4.5 Measuring how fast water sinks into the soil*

Box 8.2. Discovering conservation agriculture by chance

Things had not been going well for Amina, a farmer in a dry part of Tanzania. She wanted her four children to keep going to school, so she sold the last of her donkeys. She hoped one of her husband's five other wives would lend her donkeys so she could prepare her land for maize sowing. But the rains were late, and her co-wives needed their donkeys to prepare their own fields. Desperate, Amina decided to sow her field without ploughing it first. The co-wives called her a bad farmer, and an even worse mother and wife for not growing enough food for her family.

But later in the season, a dry spell hit the area. A lot of crops wilted and died. But Amina's plot stayed green for a long time, and her crop more or less survived the difficult period. She was able to harvest enough maize for her family for the coming year, unlike the co-wives, who harvested just one bag of maize each.

Three principles of conservation agriculture:

- *Disturb the soil as little as possible*
- *Rotate or mix crops*
- *Keep the soil covered.*

Principles of conservation agriculture

There are many different ways to practise conservation agriculture. But they all have three things in common:

1. **Disturb the soil as little as possible.** That means direct seeding or planting without ploughing or tilling, and avoiding compaction by tractors or trampling by animals.
2. **Rotate or mix crops.** It is important to mix or rotate cereals, legumes and other crops.
3. **Keep the soil covered.** That can be achieved by leaving crop residues on the ground, using mulch, and planting cover crops.

The combination is vital, because only this way is it possible to avoid weed problems, thirsty plants, erosion and runoff that carry away soil, nutrients, fertilizers and pesticides.

Box 8.3. Key features of conservation agriculture

- No burning of crop residues or fallow vegetation
- No ploughing, disking or seedbed preparation
- Green manure or cover crops part of the cropping system
- Crop residues applied as mulch
- Direct seeding or planting
- No uncontrolled grazing
- Build-up of soil organic matter
- Surface application of lime and fertilizers
- Specialized equipment for direct seeding and managing cover crops and residues
- Continuous use of crop land
- Crop rotations and cover crops to control pests.

Reduced or zero tillage and weed management

Tillage is not really necessary in most parts of the tropics. It can be a good idea if the soil has very compact layers that hinder root growth (see the next section on soil compaction). But elsewhere, it can do more harm than good.

What are the alternatives? Reduced tillage practices that do not disturb the whole soil surface but loosen only that part where the crops grow. Or zero-tillage, that leaves the soil surface undisturbed.

In reduced or zero-tillage, farmers prepare the land by slashing weeds or crop residues still on the field. They sow seeds into small slots (made by a chisel plough) or holes (made with a jab-planter or hoe). Apart from these slots or holes, the rest of the field is not disturbed. Some types of seed can even be broadcast onto mulch, without disturbing the soil at all.

Leaving the soil undisturbed will keep the soil healthy. The living organisms in the soil will all carry on, with each one in balance with the others. Ploughing and hoeing disturbs this natural balance. It harms the "good" organisms, and gives others – such as nematodes, termites and grubs – a chance to multiply and become pests or spread diseases.

Various types of equipment can be used in conservation agriculture. Some is familiar: hoes for digging planting holes, for example. Others must be made or bought specially: direct seeders, for example, or tools for managing cover crops and crop residues.

Many large farmers and smallholders in Africa already practise reduced or zero tillage. Switching to conservation agriculture is not without teething problems. You must persevere before you learn how to get the natural ecosystem working for your farm!

Weeds can be a particular problem at first. To control them, you have to create a protective layer of mulch, or plant a cover crop that shades and smothers weeds. Because the soil is not worked, only weed seeds on or near the surface will try to germinate; not the ones buried deep in the soil. It is also necessary to stop existing weeds in the field from flowering and setting seed. You have to get rid of them before they set seed. For weeds that spread through underground stems, such as couch grass, you may need to use special methods (► *Module 13 Managing weeds*).

Preventing and overcoming soil compaction

Many things can compact the soil: trampling by animals' or farmers' feet, heavy machinery, and even raindrops pounding the surface. A hard, compact layer can also form below the surface, if farmers plough or hoe to the same depth season after season. Soils get compacted more easily if they are wet. Clay soils usually suffer more from compaction than loamy or sandy soils.

Compaction is bad for many reasons:

- When soils are compacted, they lose some of their structure. The particles in the soil move closer together, and the gaps fill up. The soil can hold less air – so there is less air for microbes, roots and other soil life to use.
- Fewer and smaller gaps also means the soil can hold less water. Little water can sink through the compact layer, and water does not drain away well. If the top layer of soil is already saturated, no more rainwater can seep in, so it runs off the surface, causing erosion. Water is trapped above the compacted layer in the top few centimetres of soil, where it can evaporate easily in the hot sun. That means the soil can hold only a little water and dries out quickly, leaving crops to go thirsty.
- The soil becomes denser and harder to work. Instead of two donkeys, four strong oxen are needed to pull a plough, which trample the ground even more, compacting it further.
- Roots find it harder to push their way through the hard soil. Crops go thirsty and hungry because they cannot reach the water and nutrients they need.

► *Exercise 4.3 Assessing soil structure*

If your crops do not yield as much as you would expect, check whether there are signs of compacted soil.

- Look for signs of soil erosion, crusts on the surface, poor or uneven crop germination, slow crop growth, low productivity and lots of weeds.
- Dig small pits to check for compacted soil layers and twisted and bent roots.
- Use a penetrometer (a special tool which is pushed into the soil) to detect compacted soil layers and show how deep they are.

► *Exercise 8.2 Checking for soil compaction*

Breaking up compacted soils

It is important to break up a compacted soil before starting conservation agriculture. Here are two ways to do so:

- **Grow deep-rooted plants** or plants with a tap root, such as millet, castor bean or horseradish. You can plant them as a crop in the rotation, or as an improved fallow.
- **Use a subsoiler** – a tool that has a long blade – to break up the compacted layer. Subsoilers can be pulled by animals or a tractor. They usually work down to a depth of 30 centimetres. The best time to do this is at the end of the growing season. At the same time, you can level the ground and build bunds and checkdams to stop gullies from growing.

If the soil is acid, it is a good idea to apply lime at the same time as subsoiling (if you have already started conservation agriculture, you can broadcast lime on the surface to correct an acidity problem).

After you have broken up the compacted layer, don't disturb the soil again. From now on, it should be protected with crops, cover crops and mulch. First, plant a crop with a lot of roots, such as black oats, rye, millet and Brachiaria. Sow it at a high plant density. The dense root system will help prevent the soil from compacting again naturally. Delay the harvest of this crop as long as possible. Leave all residues on the surface, preferably until the crop is planted.

Once you have started conservation agriculture, soil compaction should not be a problem. This is because there is more organic matter in the soil, and more roots, earthworms and other organisms to open up channels. The cover crops or mulch protect the soil surface, preventing crusting and compaction in the top layer. And there is no more ploughing or hoeing to create a hardpan.

Certain cover crops are good for keeping the soil loose. They have aggressive, or dense, spreading roots that break compacted soil layers. They include sunn hemp (crotalaria), castor bean, lupin, horseradish, black oats, millet, grasses and perennial forages. Incorporate such crops in your crop rotation, or grow them as an intercrop (for example, maize–Mucuna, maize–castor bean, or maize–*Leucaena*). Over time, the hard layers will become less dense, allowing roots to reach deeper and deeper in the soil.

Some ways to avoid compacting the soil again if you use a tractor:

- Keep heavy equipment out of fields when the ground is wet.
- Reduce the number of times you go into the field with heavy equipment. Do several operations at the same time.
- Make sure that tractors always follow the same tyre tracks for spraying, harvesting, etc. That leaves the rest of the field undisturbed.
- Use the right tyres and pressure.

Managing soil moisture

Conservation agriculture is especially valuable in semi-arid areas or drought-prone regions. It manages soil moisture well: more water sinks into the soil, less evaporates from the surface, and the crop roots can reach into the soil to tap moisture deep down.

In dry areas, mixtures of crops are less common than in wetter areas because the crops may compete for water. But the soil may contain enough moisture to plant a quick-growing cover crop or fodder crop after the main growing season. This second crop can be sown before the main crop is harvested.

It is also possible to harvest rainfall in conservation agriculture. The most common method is to dig "zaï pits" (▶ *Module 11 Harvesting water for crops*). These are small planting pits, dug by hand or special equipment. You put inorganic fertilizer, compost or manure in the pit, cover it with a small amount of soil, then plant the seed. Rain collects in the pits and sinks into the soil, where the plants can reach it. This is a good way of growing maize in times of drought.

Mulch

Mulch is a layer of vegetation left on the soil surface. It can be weeds that have been slashed or hoed, crop residues left in the field, or grass or tree prunings brought in from outside.

Mulch has various benefits:

Preventing erosion. Mulch stops heavy rain from pounding the soil underneath. It stops water from running over the soil and gives it time to sink in. It traps soil particles and prevents them from being washed downhill. It also helps prevent dry soil being blown away by the wind.

► *Exercise 10.8 Soil cover to reduce erosion*

Keeping the soil cool and moist. Mulch protects the soil from drying out and being baked in the sun. Moisture and an even soil temperature are good for plants and for soil life.

► *Exercise 10.6 Mulching to reduce evaporation*

► *Exercise 10.7 The ability of soils to hold water*

Adding to organic matter. As it decomposes, mulch becomes incorporated into the soil and adds to the soil organic matter. It releases nutrients that microbes, other organisms and crops can use. And it helps improve the soil structure.

Controlling weeds. Mulch smothers weeds – something that is very important for conservation agriculture. Using cover crops and mulch, it should be possible to keep the soil covered for most of the year, or even all year round.

► *Exercise 8.3 Estimating soil cover*

The ideal mulch:

- Protects the soil surface for as long as possible
- Decomposes slowly and returns its nutrients to the soil
- Does not provide a good home for pests
- Does not create problems when planting crops
- Covers the soil at least until the next crop has grown enough to cover the ground.

The best mulch consists of tough, fairly woody materials (such as maize stalks), not just soft leaves. These tough materials last longer on the surface and decompose over time, releasing their nutrients slowly into the soil. The mulch should cover at least 80% of the soil surface (► *Exercise 8.3*). About 5 t/ha of mulch, spread evenly over the ground, is enough.

You can create a good mulch layer by growing different types of grasses and cereals (maize, sorghum, millet or black oats) in rotation. Leave the residues on the ground, on top of the remains of the previous crop, so the mulch layer builds up year after year. You will have a balanced mulch layer 3–4 years after you start conservation agriculture.

► *Exercise 5.3 Decomposition of organic materials*

Make sure the mulch is distributed evenly over the surface. If there is too much mulch in some places, it will be difficult to sow seeds and apply fertilizer. Places with too little mulch may have problems with weeds or erosion.

If you have too much mulch, don't burn it! You can:

- Use some of it to make trash lines along the contour.

- Collect some of it to feed to animals, to make hay, or to use as animal bedding.
- Collect it and spread it on other fields.

If you have too much mulch, try planting legumes (which decompose quickly) rather than grasses.

When discussing mulch, remind the participants about the exercises in ► *Module 6 Encouraging soil life*. Are termites, beetles and other organisms good or bad, and can they be managed? Ask about the participants' experiences with termites or grubs attacking crops. Explain that crops are damaged when there is an imbalance in the soil life and when there is not enough food for the different organisms – which then start eating the crops.

► *Exercise 6.1 The health of a soil.*

► *Exercise 6.2 Comparing healthy and poor soils.*

► *Exercise 6.4 Earthworms in action.*

Cover crops

Good cover crops have many features:

- They produce a lot of vegetation and cover the soil well.
- They have lots of vigorous roots.
- They do not need the soils to be very fertile, and they don't take too much moisture.
- They recycle nutrients well.
- Ideally, they fix nitrogen.
- They don't encourage pests or diseases that attack the main crop.
- They hinder the germination of weeds.
- They produce lots of seed (you may need to grow your own seed so you can sow the cover crop again next season).
- When they die, it is easy to manage the residues.
- You can use any type of plant that has many of these features. Here are some suggestions:
- **Grasses and cereals** such as maize, sorghum, millet, black oats, white oats, rice, rye, triticale, Bracchiaria. They cover the soil with a dense mat, and have many roots.
- **Legumes** such as vetches, sunn hemp (*Crotalaria juncea*), Desmodium, Mucuna, cowpea, pigeonpea, lablab, lupin and Glyricidia. They fix nitrogen and decompose quickly.
- **Other plants**, including radish, horseradish, castor bean, pumpkins and watermelons. They have strong, vigorous roots.

► *Exercise 8.4 Looking at roots.*

It is a good idea to plant a mixture of grasses, legumes and other species as a cover crop. That will help avoid pests and diseases, and will lead to a healthier soil.

Millet, black oats, rye and horseradish do not need a lot of nutrients, though they respond well to fertilization. They need some soil moisture to germinate and start growing, but then they can survive a few weeks without rain.

Some cover crops can be used for food or fodder. Examples are cereals, grasses, cowpea, pigeonpea, pumpkins and watermelons.

Cover crop species that grow well in semi-arid areas include lablab, pigeonpea and cowpea. Species that prefer sub-humid areas include *Mucuna*, *Gliricidia*, hairy vetch, and *Desmodium*.

You may be able to find other plants that make good cover crops. Ask farmers and researchers to identify and test them.

What is the difference between a green manure and a cover crop? A green manure is grown so it can be ploughed into the soil. A cover crop is left on the soil surface. Green manures cannot be used with conservation agriculture because the ploughing would disturb the soil. ► *Module 5 Using organic materials.*

Managing crop residues and cover crops

In conservation agriculture, you should try to build up a layer of dead material covering the ground. That layer must not break down too quickly – otherwise it will no longer protect the soil surface. That is why tough, woody plants (like grasses and maize stalks) make better mulch than legumes.

Leave the cover crops to grow as long as possible – until just before they produce viable seeds (i.e, during the milky stage in grain crops). Then kill the cover crop to prevent seeding and regrowing the next season, when you want crops in the field. You can kill the cover crop by slashing, using a knife roller, or using a herbicide. Leave the residue on the ground as mulch.

If you plan to use planting equipment, it is a good idea to cut the residue into fairly large pieces – say 20–25 cm in length. That prevents the residue from clogging up the planter when sowing time comes round. Don't cut the residue into very small pieces, or it will decompose too quickly.

However, for some crops such as cotton, you should cut their residues into small pieces to speed up decomposition and to kill diseases that might survive in the residues.

Instead of slashing or using a knife-roller, you can use a herbicide to kill the cover crop. Herbicides leave the dead cover crop standing in the field, so it decomposes slowly. Systemic herbicides such as Glyphosate and 2,4-D, take 6–10 days before they work. Contact herbicides, such as Paraquat, work much quicker. If you need to keep the soil covered for a long time, choose a systemic herbicide. If you plan to plant the next crop immediately, a contact herbicide is better.

If you use herbicides, remember they may be poisonous! Take the proper precautions when mixing and using them, and store them safely, away from where children and animals can reach them.

For more on organic matter management, ► *Module 5 Using organic materials.*

► *Exercise 5.3 Decomposition of organic materials.*

► *Exercise 5.4 Sources of organic material.*

Crop rotations and intercropping

Figure 8.3. Mixed intercropping: no rows make it hard to weed and harvest

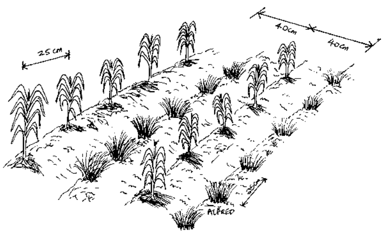


Figure 8.4. Row intercropping with alternate rows of maize and beans. Easy to weed and harvest.

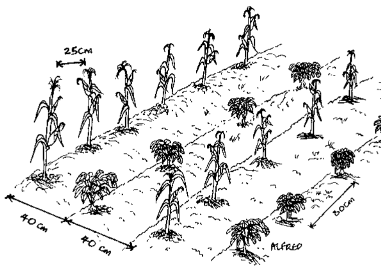


Figure 8.5. Row intercropping with alternate rows of a cereal and a grass cover crop

Many farmers are used to growing crops as pure stands. And they plant the same crop year after year on the same fields.

That is bad for several reasons:

- It encourages certain types of pests, diseases and weeds.
- The crop's roots reach into a certain layer of the soil, and use up the nutrients there. They do not use the nutrients above and below this layer.
- If the monocrop is a cereal such as maize, it does not fix nitrogen in the soil.
- If the crop fails, the farmer has nothing else to fall back on.
- Crop rotations and crop mixtures avoid these problems, and have other benefits too:
- **They tap nutrients throughout the soil.** Different crops have different rooting patterns. They reach nutrients and water in different soil layers.
- **They improve the soil structure.** Some crops have strong, deep roots. They can break up hardpans, and tap moisture and nutrients from deep in the soil. Others have many fine, shallow roots. They tap nutrients near the surface and bind the soil. When the roots die, they leave many holes and channels that air and water can use to get into the soil.
- **They increase soil fertility.** Legumes (such as groundnuts and beans) fix nitrogen in the soil. When their green parts and roots rot, this nitrogen can be used by other crops such as maize. The result is higher, more stable yields, without the need to apply expensive inorganic fertilizer.
- **They help control weeds, pests and diseases.** Planting the same crop season after season encourages certain weeds, insects and diseases. Planting different crops breaks their life cycle and prevents them from multiplying.
- **They produce different types of output.** Growing a mix of grain, beans, vegetables and fodder means a more varied diet and more types of produce to sell.
- **They reduce risk.** A single crop may fail because of drought. It may be attacked by pests. Or its market price may be low when time comes to sell it. Producing several different crops reduces these risks.

When planning a crop rotation, be sure to rotate among crops that are not alike. For example, it is better to follow a maize crop (a cereal) with soybean (a legume) than with sorghum (another cereal). That will avoid a build-up of weeds, pests and diseases that prefer similar types of plants.

Even crops that are usually grown as a monocrop in clean fields, like cotton, produce well under conservation agriculture.

► *Exercise 14.4 Mixed cropping versus monocropping.*

► *Exercise 8.5 Crop rotation.*

Converting to conservation agriculture

What you will need

Both large- and small-scale farmers can use conservation agriculture – though they will use different techniques and equipment. See the section on *Implements* below for a list of equipment you might need.

More important than equipment are:

- Confidence and open-mindedness to try out new ideas.
- Technical assistance and advice.
- Seeds of suitable cover crops.

There is no single recipe for starting conservation agriculture. And it may not be easy. The best way is to start small, on part of your farm. Choose one of your better plots – where the soil is healthy and there are not too many weeds. Test different methods, then use the ones that suit you and your farm. Find out what works, then gradually increase the area and expand to more marginal plots. If you start big, then your early mistakes matter more, and you may get frustrated and give up.

Before you start

- Make a map of your farm showing the different soils and terrains (▶ *Exercise 2.1*).
- Check the conditions of each area in the farm: the soil, vegetation, land use, erosion, weeds, amounts of fertilizer and lime applied, etc. (▶ *Exercise 4.1 Soil walk*).
- Select the best area to start with, because this will give the best chances of success.
- If the land has not been cultivated recently, remove tree trunks and big roots.
- If necessary, use a subsoiler to break up the hardpan, and apply lime to correct soil acidity.
- Build or repair structures such as terraces, drains and *fanya juus*.
- Work out a suitable mixture of crops and crop rotation to use in the first few years. This will depend on what seeds are available, what grows well in your area, and whether you can sell the produce (▶ *Module 15 Farm management, marketing and diversification*).

Applying conservation agriculture

If the ground is covered with vegetation which protects it against rain and erosion, kill it with a herbicide, a knife roller, or by slashing it. The next crop can be sown over the residues at the beginning of the rainy season. If the ground is not already well protected, begin by sowing a crop that forms mulch – probably a grass or cereal, as these have lots of roots and their residues decompose slowly.

In the next season, sow a different crop, following the rotation plan you have made. Do not plough or turn the soil. Instead, plant the seeds of the new crop through the mulch and stubble of the previous crop. You might even be able to sow one crop before harvesting the previous one.

Plant cover crops and use mulch to keep the soil covered for as much of the year as possible. Choose commercial crops not just for the money they bring in, but also for the amount of vegetation they produce.

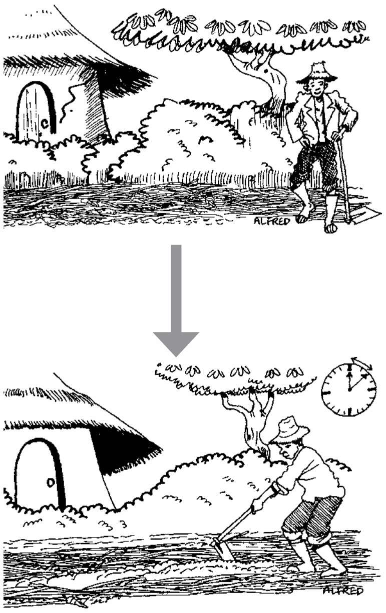


Figure 8.6. Mulch suppresses weeds, so saves time when you are preparing the field for planting

Transition stage

If your soil has been damaged by many years of conventional tillage and erosion, you may have to switch to conservation agriculture gradually. A transition stage is needed to remove the hardpan, overcome soil compaction, and build up organic matter in the soil.

Subsoiling usually is the first step. If there is a severe hardpan, it will bring spectacular results. That helps convince farmers that a positive change is possible. Depending on the soil, you may have to repeat the subsoiling after some years, even if you are practising conservation agriculture.

Deep chiselling of the entire field might be needed during the first and maybe the second year before you switch to a true conservation agriculture system.

Adding lime may be needed to make the soil less acidic.

Planting all crops at very high densities. If possible, plant strips of different crops. That builds up the organic matter in the soil and controls weeds.

Good weed management is vital. You have to control weeds, even between cropping seasons, to stop the weeds from producing seeds. You can do this by planting cover crops or by slashing the weeds.

The more problems a soil has, the longer it will take for conservation agriculture to show results. Sandy soils restrict crop roots less than clayey soils. Adding organic matter to sandy soils via mulch and cover crops can produce spectacular yield increases.

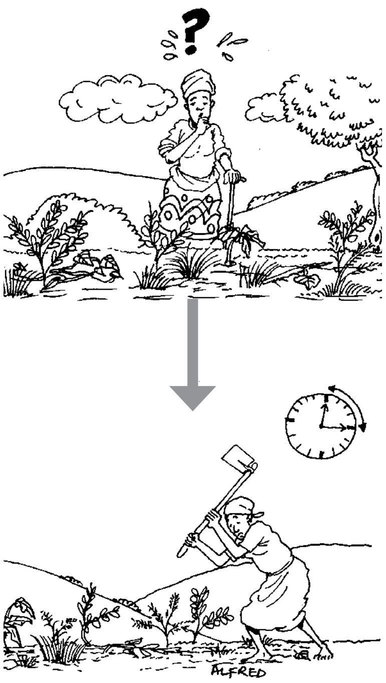


Figure 8.7. No mulch? Get ready to sped a lot of time preparing the field and fighting weeds!

Weeds and weed control

Check the field for weeds frequently, and kill weeds before they can set seeds. Leave the dead weeds in the field as mulch. In this way, the farmer's enemy is turned into a friend.

Certain types of weeds can be a problem in conservation agriculture:

- Weeds that are resistant to herbicides (if you use them).
- Perennial weeds and those that reproduce through shoots or underground stems, such as *Cynodon dactylon, Digitaria insularis* and *Sorghum halepensis*.

You should use several different methods to control weeds:

- Plant crops densely to limit the amount of light and space that weeds can get.
- Rotate crops to avoid certain types of weeds from becoming dominant.
- Plant cover crops between the main crop rows to cover the soil.
- Keep the soil covered throughout the year, with crops, cover crops or mulch.
- Weed the fields frequently by slashing the weeds.
- Control weeds during the fallows to prevent them from flowering and setting seed.

Table 8.1. Types of equipment for conservation agriculture

	Tractor or animal power	Human muscles
Breaking hardpan	Subsoiler Chisel or ripper	Hoe Pickaxe
Planting, applying fertilizer	Ripper-planter Direct seeder	Planting stick Jab planter
Weed control	Knife roller Sprayer	Panga Zamwipe Knapsack sprayer Hand-pulled sprayer

Figure 8.8. A Zamwipe weed wiper looks like a broom with a sponge on one end and a bottle of herbicide on the handle

- Apply herbicides if necessary. It is best to apply them in the early morning, after the dew has disappeared, when the weeds absorb the herbicides best.

► *Exercise 13.1 Recognizing weeds.*

► *Exercise 13.2 Weed management trial.*

Implements

What equipment you need depends on the size of the area you want to put under conservation agriculture, and whether you use tractors or animal power, or your own muscles for heavy farm work (► *Table 8.1*).

For small-scale farmers, some of the equipment is familiar: hoes, pangas, pickaxes and sprayers. Other equipment is less familiar: jab-planters (hand-operated seed planters), Zamwipes (herbicide applicators that look like brooms). Note that you don't actually need any equipment other than a hoe and a panga.

Farmers who use tractors or animal power can use special equipment such as ripper-planters, subsoilers, direct seeders and knife rollers. Some designs can be pulled by animals, others by a tractor.

- **Chisels or rippers** are sharp metal points that can be attached to an ordinary plough beam. They are used to break up crusts, shallow hardpans and compacted soils.
- **Subsoilers** are used to break up hard or compacted soil layers deeper in the soil – down to 60 cm with a tractor and 30 cm for animal power. They can also be attached to an ordinary plough beam.
- **Direct seeders** are used to manage residues on the surface and at the same time place seeds and fertilizer in the soil.

► *Exercise 8.6 Using a knife roller.*

► *Exercise 8.7 Using a direct seeder.*

Livestock

Can you practise conservation agriculture and also keep livestock?

Yes, but you have to manage your animals carefully. And you must make sure your neighbours also control their animals to avoid damaging your conservation agriculture fields.

Conservation agriculture produces a lot of green matter that you can use as livestock feed. You can use fodder grasses as part of your crop rotation: they have lots of roots, so help improve the soil. You can cut the grass and feed it to animals in their stall, make hay or silage, or let the animals graze on the fodder. Legume cover crops also make good animal fodder.

Do not let animals graze too much, as you want to leave as much vegetation in the field as possible to keep the soil covered.

► *Exercise 9.7 Making silage.*

► *Exercise 9.8 Making hay.*

Labour considerations

Conservation agriculture generally takes less work than conventional farming, as it is not necessary to plough or harrow to prepare the seedbed. That saves time and effort, and means that the crop seed can be sown earlier, bringing forward the harvest date and avoiding damaging droughts at the end of the season. Conservation agriculture can mean more work weeding in the first few years, but this work can be spread out over a long time. Eventually, the cover crops, mulch and herbicides control weeds, so less work is needed.

If you practise conservation agriculture, you may be able to farm more land, start another enterprise (such as processing farm outputs), or get a job elsewhere during your spare time. If you manage to grow more on the same plot of land, you might also choose to reduce the area you cultivate to allow part of your land to lie fallow and regenerate.

Because less work is needed, conservation agriculture is a good option for families that are short of labour – for example, if the young people are away working in town, or if family members are ill.

As a facilitator, help the farmer field school members use their study plot to look at the effects of conservation agriculture on productivity, labour needs and the types of crops produced.

Exercise 8.1 The umbrella

Before going into details on conservation agriculture, it is important to discuss with farmers the need to protect their soil.

Steps

1. Ask one of the participants to put on the sunglasses. Ask why people wear sunglasses.
2. Ask another participant to put on the hat. Ask why people wear hats.
3. Get other participants to put up the umbrellas. Ask why we use umbrellas (to protect against both sun and rain).

Questions to stimulate discussion

- What is the equivalent of the umbrellas and hat in farming?
- Why is it important to protect the soil from the rain and sun?
- What is the difference between a small umbrella and a large one?

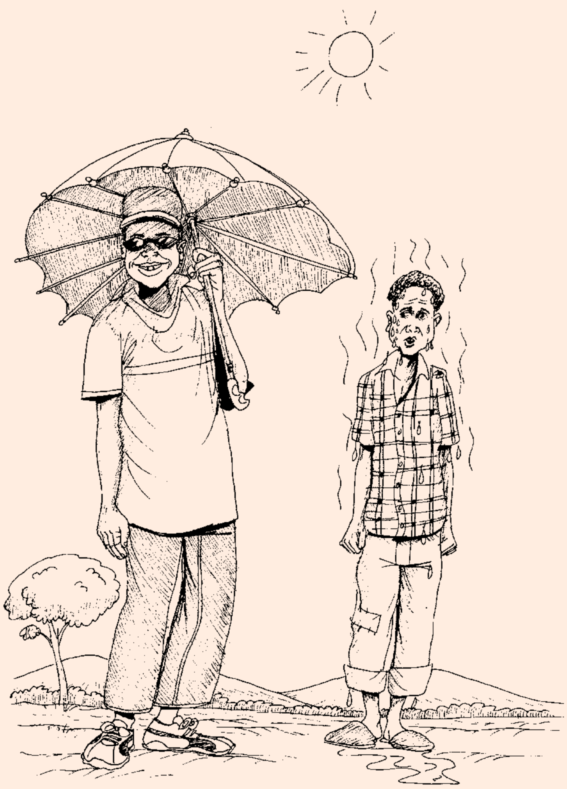


Figure 8.9. Keeping the soil covered is like using an umrella against the rain and sunglasses against the sun

Learning objectives

Understand the function of a soil cover.

Convince farmers to conserve their soil.

Understand the need to cover the soil.

Timing

Either as an introduction to conservation agriculture, or at the very end when you review conservation agriculture concepts.

Preparation

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Duration

5–10 minutes.

Materials

Sunglasses, hat, three different sizes of umbrellas.

Adapted from

FAO (2002)

Exercise 8.2 Checking for soil compaction

Learning objectives

Check various soils for compaction.

Timing

When discussing soil compaction. This exercise can be done at the same time as ► *Exercise 4.3 Assessing soil structure* or *Exercise 4.5 Measuring how fast water sinks into the soil*.

Preparation

Choose a field where you suspect compaction might be a problem.

Duration

1.5 hours.

Materials

Spades or hoes, knives, large pieces of paper, marker pens.

Steps

1. Dig a small pit in the field where you suspect compaction might be a problem, for instance in a place where water collects on the surface.
2. Look for the following telltale signs of compaction: twisted and malformed roots, signs of waterlogging (usually grey mottling), dense soil layers without any root growth and accumulated salt, sand and clay in certain soil layers.
3. Test the hardness of the soil at different depths by pushing the knife horizontally into the side of the pit.
4. Ask small groups of participants to dig several pits in different parts of the field (or in different places that have been managed differently, such as a vegetable garden, a pathway, or a conservation agriculture field). Ask them to note what they see.
5. Ask the participants to report back what they have seen in each location.

Questions to stimulate discussion

- What differences did you see in each place? What caused these differences?
- What effect might compaction have on the crop roots? On the movement of water and air in the soil? On how easy it is to work the soil?
- How might it be possible to break up a compact layer?

Exercise 8.3 Estimating soil cover

Knowing how to manage crop residues is the key to success with conservation agriculture. People always talk about soil cover. Some people even say it is necessary to have a certain percentage of soil cover for conservation agriculture to work. This exercise shows an easy way to estimate the percentage of soil cover.

For most crops, conservation agriculture systems help maintain residue cover levels well above 30%. The exceptions are crops like soybeans, cotton and sunflowers that produce either low quantities or fragile residues which decompose quickly.

Steps

1. Throw the rope randomly in the field, and straighten it out.
2. Count the number of knots that touch or lie over some kind of soil cover – residues, green plant material, stones, etc., and not over bare soil.
3. Multiply the number of knots by 10. This gives the percentage soil cover. For example, if 3 knots touch or lie over mulch or a cover crop, this means you have 3 x 10 = 30% soil cover.
4. Repeat in at least ten different places in the plot, then calculate the average percentage.

Questions to stimulate discussion

- Why is soil cover important?
- How much soil cover is ideal? (Answer: aim for about 80%.)
- How can you increase the amount of soil cover in the field?

Learning objective

Estimate the percentage soil cover using a rope.

Estimate the soil cover in a specific field.

Timing

When discussing the importance of soil cover.

Preparation

Tie a knot at every 50 cm in a 5 m long piece of rope, so there are 10 knots in all.

Duration

30 minutes.

Materials

Rope (5 m long), notepaper, pencils.

Adapted from

FAO (2002)

Exercise 8.4 Looking at roots

Learning objectives

Observe root systems of different crops and cover crops.

Understand how roots help build soil.

Be able to select crops or cover crops to tackle certain soil problems.

Timing

When discussing the importance of cover crops and crop rotation.

Preparation

Identify five different crops or cover crops that might be useful in crop rotations in the area. Either sow them before the farmer field school starts, or find where they are growing in the fields. Choose crops with very different root systems: deep taproot, wide-spreading shallow roots, many fine roots, few coarse roots, etc.

Duration

2 hours.

Materials

Spade and knife or trowels, buckets of water to rinse the roots, plastic sheets, measuring tape, notepaper, pencils.

Adapted from

FAO (2002)

Knowing the rooting patterns of different crops enables farmers to choose the best crops for different jobs – breaking a hardpan, recycling nutrients from deep in the soil, improving the soil structure, increasing the amount of organic matter in the soil, and so on.

Steps

1. Ask the farmers whether they know the five crops and how they use each one.
2. Split the group into five subgroups, one for each crop.
3. Ask each group to dig a pit next to one plant of their chosen crop. Tell them to dig carefully so they do not damage the plant's roots. The pit should be as deep and as wide as the roots.
4. Use knives and trowels to expose the roots.
5. Measure how deep the roots reach down.
6. Uproot the plant, taking care not to damage the roots (you can cut the stem if necessary). Rinse the soil from the roots. Lay the plant on the plastic sheet and study its roots.
7. Ask the group to describe the roots: fine, many, coarse, thick, few, long, nodules, etc.
8. Ask the group to draw the roots and to label the drawing.

Questions to stimulate discussion

- Did you find a lot of differences between the roots of the different crops?
- How does each type of root affect the soil?
- How does each type of root affect the next crop?

► *Exercise 6.8 Becoming a root doctor*

Figure 8.10. Planning a crop rotation

Exercise 8.5 Crop rotation

This exercise helps farmers choose the best crop rotation for their fields.

Steps

1. Ask the participants whether they rotate crops in their fields. What crops do they use, and in what order? Why do they choose those crops?
2. Divide the participants into groups of 4 or 5. Ask each group to visit nearby farms and ask the farmers about their crop rotations, and why use those crops in that order. Each group should interview about five farmers.
3. In plenary, ask what the general crop rotation patterns are in the area. Write the various rotations on a large sheet of paper. Ask whether this rotation pattern is the best one. If not, why not? How could it be improved?
4. Ask why crop rotation is important, and how the farmers choose the crops to rotate. List their reasons on paper. They may mention the following (if they don't, bring them to their attention):

- Switch among crops that have different pests and diseases
- Don't rotate crops that are similar to each other
- Plant deep-rooting crops after shallow-rooting crops (an advantage is that the deeper rooting crop takes up leftover nutrients).
- If possible, include a green manure in the rotation.
- Rotate among at least three different types of crops.

5. Ask which are the important vegetable crops and which are their relatives (► *Box 8.4*).
6. Divide the participants into five groups, and assign one family of vegetables to each group. Ask each group to propose rotation schedules that cover at least 3 seasons. Note that the rotation schedules must be practical in the area. ► *Table 8.2* shows examples of good rotation schedules.

Questions to stimulate discussion

Compare these proposed rotations with the ones the farmers suggested at the start of the session. How are they different?

Are the proposed rotations different from what farmers in the area do? Why?

Would the farmers follow the proposed rotations? If no, why not?

Do you think rotation can be useful when growing maize or sorghum?

Table 8.2. Suggested crop rotations

Field	Season 1	Season 2	Season 3	Season 4
1	Tomato (potato family)	Groundnut (legume)	Kale (cabbage family)	Green manure or cereal
2	Garlic (onion family)	Pepper (potato family)	Beans (legume)	Green manure or cereal
3	Squash (melon family)	Broccoli (cabbage family)	Onion (onion family)	Green manure or cereal

Learning objective

Create awareness about how to choose crops in a rotation scheme.

Timing

When discussing the issue of crop rotation. Also when selections of cropping sequences are made.

Preparation

Identify some farms in the neighbourhood that have a clear variation in rotation practice.

Duration

1 to 2 days.

Materials

Notepaper, pencils, large pieces of paper, marker pens.

Adapted from

FAO/CABI (2001)

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Box 8.4. Families of vegetables

Potato family: potatoes, tomato, pepper, eggplant

Melon family: squash, cucumber, watermelon, muskmelon, pumpkin, chayote

Cabbage family: Cabbage, kale, Chinese cabbage, cauliflower, broccoli, sawi, kailan, mustard, radish, rape, pak choi, turnip

Legumes: Sweet pea, pea, yard-long bean, French bean, winged bean, groundnut, soybean, alfalfa, clovers

Onion family: Onion, spring onion, garlic, shallot, leek, chives

Exercise 8.6 Using a knife roller

Learning objectives

Understand how a knife roller works and what it does to crop residues.

Adjust the weight of a knife roller.

Timing

When discussing crop residue management.

Preparation

Find places with various cover crops or weeds where you can demonstrate the knife roller. Find places with woody stems, straw, legumes, grass, and so on.

Duration

2 hours.

Materials

Knife roller.

Adapted from

FAO (2002)

Knife rollers (▶ *Figure 8.11*) are a good way to manage crop residues and weeds. There are various designs that can be pulled by tractors or by animals.

When the knife roller is pulled along, the knives bend over the standing crop or residue, crushing and chopping them.

Steps

1. Explain the parts of the knife roller and what they do.
2. Show how to operate the knife roller.
3. Study what the knife roller does to different types of cover crops and weeds.
4. Increase the weight of the knife roller (e.g., by putting a bag of sand on it). See what effect that has on the cover.

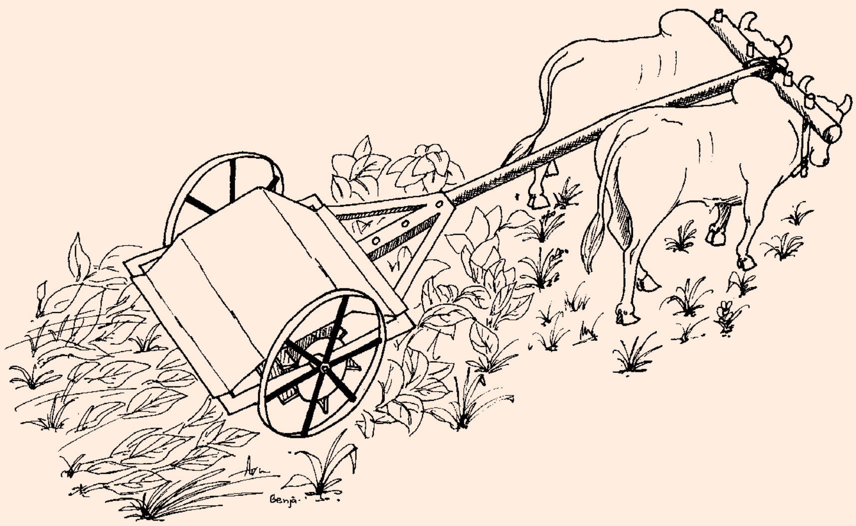

Figure 8.11. A knife roller

Exercise 8.7 Using a direct seeder

Direct seeders (► *Figure 8.12*) manage residues on the soil surface, and at the same time place seeds (and sometimes fertilizer) in the soil.

Steps

1. Explain the various parts of the direct seeder and what they do.
2. Explain how to use the direct seeder.
3. Explain what the seed plates do (there are plates with different-sized holes for different seeds).
4. Show how to operate the direct seeder. Check the planting depth and the placement of fertilizer.
5. Try out the seeder with different types of seed and different seed plates.
6. Adjust the length of the chain between the draught animal and the seeder. Check how this affects the seed placement and soil cover.

Questions to stimulate discussion

- What would happen if you choose seed plates with holes that are too big for the seeds?
- How can you keep the rows the same distance apart?
- If the seeder is not well adjusted, what happens to the soil cover? How can you prevent this problem?
- What would happen if you use oxen or horses instead of donkeys to pull the seeder?

Learning objectives

Understand how a direct seeder works.

Adjust the sowing depth of a direct seeder.

Timing

When discussing direct seeding.

Preparation

Find a place with soil cover that you can use to demonstrate the direct seeder.

Duration

2 hours.

Materials

Simple (animal drawn) direct seeder, different seed plates for seeder, different seeds (maize, beans, etc.), fertilizer.

Adapted from

FAO (2002)

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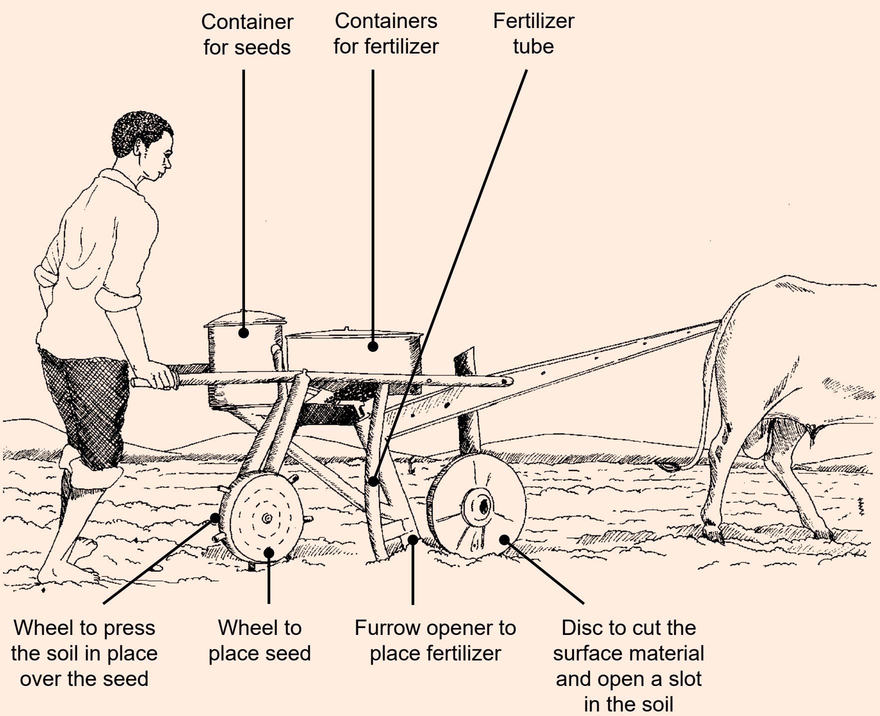

Figure 8.12. Direct seeder

Module 9. Managing livestock

Livestock are an important part of many farms. Domesticated animals – cattle, goats, sheep, horses, donkeys, camels, pigs and poultry – affect the management of land and water on the farm in several ways.

- They eat feed. They may graze on pasture, or on crop fields after harvest. Or the farmer may bring feed to the animals in their pen or stall.
- They produce manure, which is a valuable source of nutrients and organic matter.
- Oxen, donkeys and horses can pull ploughs and other implements.
- They can trample the soil and cause erosion.

This module focuses on two important aspects livestock management in relation to crops: how to improve the production and use of manure, and how to produce animal fodder.

Learning objectives

After studying this module, you should be able to:

Understand how livestock affect the productivity of the crop and of the farm as a whole.

Think of ways to improve how you manage livestock to enhance the productivity of the soil.

Better integrate animals and crops in your farm.

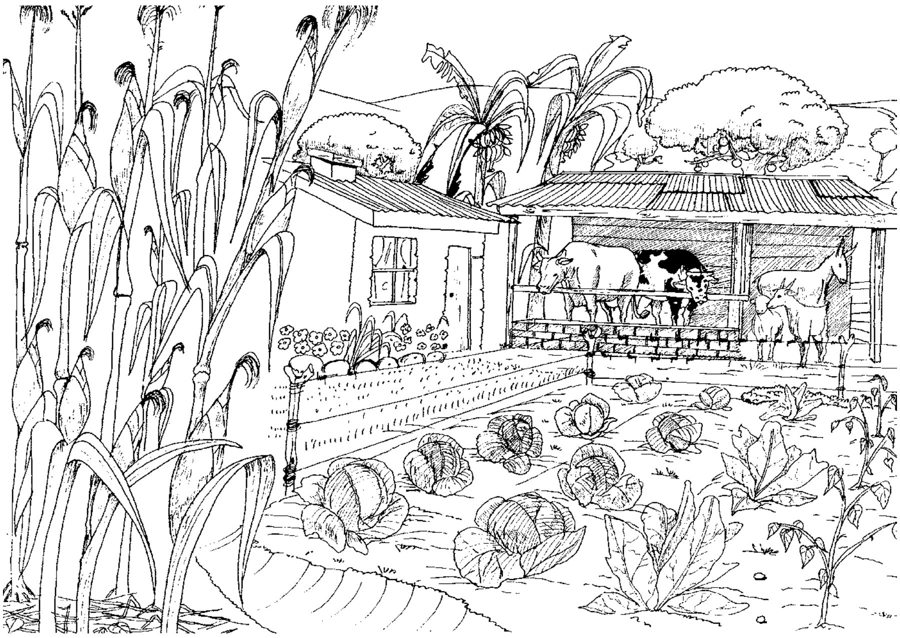

Figure 9.1 Livestock should be integrated into the overall farm system

9

Animal manure

Animal manure is a major source of soil nutrients on small farms. Animals naturally fertilize the land they graze on. Farmers can also collect manure from stalls or kraals and carry it to the fields to use it as organic fertilizer.

Different types of manure contain different amounts of nutrients (► *Table 7.3*). The amount depends on the animal species and the quality of feed they have been given. Not surprisingly, animals that have been given good quality feed (such as feed supplements) produce good-quality manure. Animals fed only on poor grasses will produce poor-quality manure. Pale-coloured manure that is full of fibre contains fewer nutrients than dark manure.

Manure has less major nutrients (nitrogen, phosphorus, potassium) than inorganic fertilizer, but it has several advantages:

- It adds organic matter to the soil, so encourages soil life (it is the basic food for soil organisms) and increases the amount of water the soil can hold.

Box 9.1. Cattle in the *kibanja*

"Kibanja" is the name for homegardens in Kagera Region, in northwestern Tanzania. Local people use these gardens to grow coffee and bananas. This type of garden has existed in the area for more than 300 years.

The kibanja is fertile because farmers collect manure from their livestock kraals and bring it to the kibanja to use as fertilizer. They also used to dig shallow pits in the kibanja to use as toilets for a few days before covering them over.

An epidemic of foot-and-mouth disease killed many cattle, leading to less manure being applied and a sharp drop in fertility of the kibanja. Attacks by banana weevils and nematodes also rose.

Apart from manure, farmers also bring in crop residues from their other fields and grasses to use as mulch around the coffee bushes. It is easiest to apply these inputs close to the house, so soil fertility and yields are highest close to the house and drop off gradually in the further corners of the garden.

► *Exercise 9.1 Looking at crops and livestock*

- It contains micronutrients which crops need to grow.
- It is free! Though labour is needed to manage farm manure and carry it to the fields

► *Module 5 Using organic materials*, *Module 7 Managing plant nutrients* and *Module 10 Managing rainwater* for more.

Even low-quality animal manures are valuable for these reasons. You may need to supplement them with green manures or inorganic fertilizers to make sure the crop gets the right amounts of nutrients to grow, be healthy and produce seed.

Farm animals recycle nutrients from other parts of the farm. They eat crop residues, forage crops, tree prunings and kitchen waste. They can be grazed on natural vegetation or fed with fodder cut from roadsides or wetlands. They can also be fed with bought supplements to improve their nutrition and milk and meat productivity.

► *Exercise 7.3 The bottle game: Nutrient movements*

Good manure – and more of it

How you manage your farm animals affects the quality and amount of manure they produce. The housing, feed and health care are particularly important.

Housing and health care

It is not necessary to use expensive materials for a livestock shed. Use local materials if you can – they are cheap or free. The shed should provide:

- Enough space for the animals to lie down, stand up and move freely.
- For poultry, separate nests for egg laying, and if possible sand baths and a way to keep the droppings away from the birds (e.g., a shed with a slatted floor).
- Protection from hot and cold, and shelter from direct sunlight and rain.
- Sufficient ventilation, but also protection from draughts.
- Suitable bedding materials and a proper walking area to prevent foot and leg problems.
- Clean conditions to prevent diseases from spreading and to keep the animals, eggs and milk clean.
- Sheltered pits or heaps to collect and store manure (including the urine, which contains lots of valuable nitrogen).

Feeding and watering livestock

More and better feed means more and better manure. Good-quality feeds contain more nutrients, and animals prefer to eat them – so they eat more. The resulting manure is richer in nutrients and is better for the soil.

How much feed does a farm animal need? That depends largely on how much it weighs, and whether it is producing (growing, pregnant, or producing milk). A normal, productive animal needs to eat about 3% of its body weight in forage (in terms of dry matter) every day. For a mature local tropical cow weighing 200–300 kg, that means between 5 and 9 kg of forage (dry matter equivalent) a day.

If you are unable to obtain this amount of feed from your own farm or other sources, you need to find supplementary feed (hay, silage, concentrates) to bridge the gap.

Milking animals need extra protein. About 30–40% of the feed for milking cows and goats should be leguminous forages. The beans and pods contain the most protein, but you can also feed legume leaves and stalks, which provide energy. Residues from groundnut and cowpea contain quite a lot of protein. You may also be able to get protein-rich supplements such as oilseed cakes made from sunflower, cotton and sesame. Milling bran and broken grains of maize, wheat, sorghum and rice are lower in protein but still very valuable.

Milking animals need a lot of water. Make sure they get enough.

Draught animals also need special attention. They have to be in the best condition to pull ploughs and carts. Weak animals will not have energy to work hard or for a long time. Give them enough feed, especially of feeds high in energy, such as grain. Draught animals sweat a lot, especially in hot weather, so they need to drink a lot of water.

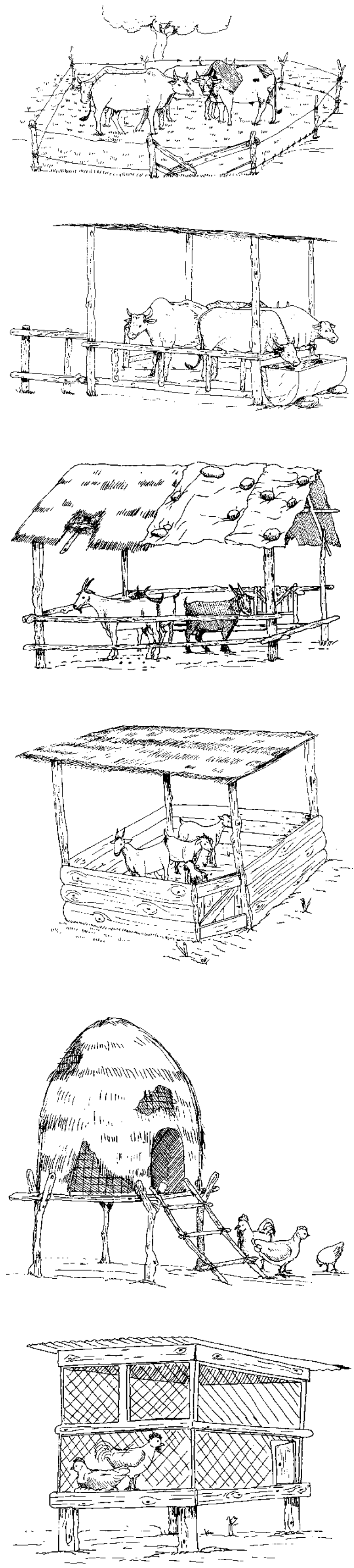

Figure 9.2. Animal housing should provide shelter and be easy to keep clean

Keep your animals happy and healthy – and they will keep you healthy and happy

All farmers know that water is important for their animals' health and productivity. It is also important for the manure: thirsty animals do not produce good manure. Make sure they get enough water, close to their stall or pen so they do not have to walk a long way for a drink, and so you don't have to carry water a long way to them. You can collect rainwater from roofs by installing gutters leading to a tank, or build a cistern or pond. ► *Module 12 Harvesting water for people and livestock* for more ideas on how to collect water.

► *Exercise 9.2 Fodder plants.*

Bedding materials

Bedding materials keep the floor of stalls soft, dry and clean. That helps keep the animals healthy and milk clean. The bedding soaks up dung and urine, so you need to replace it from time to time. The used bedding is a rich source of nutrients, and is particularly valuable for composting (► *Module 5 Using organic materials*).

You can use all kinds of material as bedding: straw, leaves and twigs, husks, and so on. You can replace it every day, or keep them for several months by adding fresh materials on top.

Make sure the bedding is protected from the rain to prevent the nutrients it contains from being washed away.

► *Exercise 9.3 Bedding materials.*

Managing manure

How you store and use manure also affects its quality.

Manure is valuable! Keep it and use it the right way.

Manure contains the most nutrients when it is fresh. Leaving it in the pen, exposed to the sun and rain, will let the nutrients escape into the air and ground water. Animals can trample it, making it harder to collect and use.

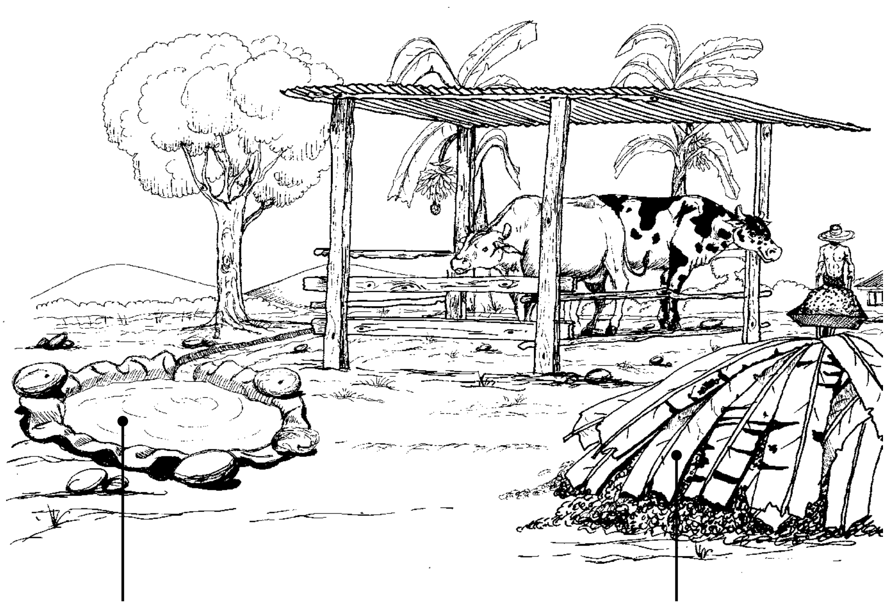

Figure 9.3. How to keep liquid and soild manure before you use it

If the manure gets trampled into the ground, it is hard to collect and heavy to carry, and it contains fewer nutrients per kilogram. Try to avoid this by collecting it when it is still fresh, or by using bedding to absorb the urine.

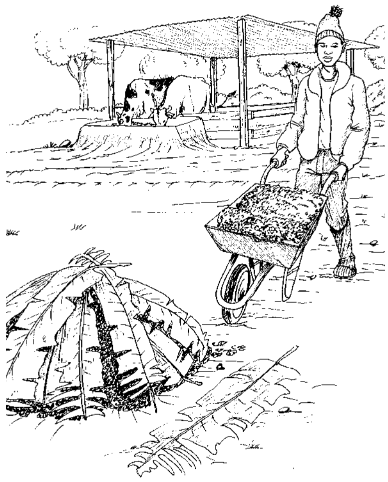

Figure 9.4. Put the manure pile downslope from the cattle shed

It is easiest to collect manure if you keep your animals in a stall and feed them with cut fodder. Or you can confine the animals in a kraal or pen overnight and let them out to graze during the day. You can then collect the manure from the pen. You can move the kraal every now and then to fertilize a different part of a field.

Collect the manure into a pile, then cover it with banana leaves, grass or a sheet of plastic to keep the nutrients; this prevents losses into the air and soil. Make the pile:

- Downslope from the livestock pen, to make collecting manure easier
- On clayey ground (or on a plastic sheet) so the nitrogen-rich urine does not soak away
- Under a tree to keep it shaded.

Dig a pit or trench downslope from the pile to collect liquid coming from it (and from the stall or stable too). Or build an earth bund around the pile to stop water from flowing in and carrying away nutrients. The liquid in the pit makes excellent fertilizer for vegetables.

In drier areas, you can dig a pit to hold manure instead of piling it up.

If you have used bedding material, rake it up along with the manure to absorb the urine, which is rich in nitrogen and potassium. If you have not used bedding material, mix the manure with chopped straw, dry grass, crop residues or leaves to soak up the urine. You can also mix green leaves and mineral fertilizers with manure to improve its nutrient content.

Make sure the pile of manure does not get too hot or dry. If white fungus threads or spots appear, the manure is too dry; dampen it with water or urine. A yellow-green colour or a bad smell is a sign that the manure is too wet and does not have enough air. If the manure is brown to black throughout the heap, conditions are ideal.

The farmer field school can check what farmers think makes good quality manure. For example, small-scale farmers in Western Kenya preferred dry manure that could be applied easily over dark manure that was richer in nitrogen.

► *Exercise 9.4 Different types of manure.*

► *Exercise 9.5 Manure at different times of year.*

Keep the manure until you need to apply it in the field. You can apply it in various ways: a few weeks before planting, in planting pits (for example for maize), or in furrows alongside rows of growing crops. You can also use manure, along with other plant materials, to make compost.

► *Module 5 Using organic materials.*

In intensive zero-grazing, a lot of the nutrients are in the urine, and it may be possible to collect the dung and urine separately. Remove the dung twice a day, and allow the urine to drain into a pit. You can use this urine as top-dressing or to control pests. You can also store a mixture of dung and urine in a closed pit. Every two weeks (while it is still reasonably fresh), incorporate this slurry into the soil in your fields.

Managing crops and fodder crops

Small-scale farmers may find it difficult to grow fodder crops: they say they need to grow food or cash crops instead. But it may be possible to grow more fodder without sacrificing any (or too much) land used for other crops. For example, you might be able to:

- Use grass or leguminous cover crops and green manures as fodder.
- Plant hedges of fodder shrubs and trees.
- Plant fodder grasses on bunds or contour ridges built to control runoff and soil erosion.
- Sow grass fallows or green manures as part of the crop rotation.
- Improve the use of forage and crop-residues.
- Improve the yield and quality of pastures, forages and crop residues.

Legumes make good fodder, and they are a good way to improve soil productivity, especially of less fertile soils a long way from the homestead. You can sow forage legumes during the short rains, or as a relay crop planted between the rows of a long-season crop. The legume will continue growing after the main crop is harvested, and uses any moisture that is still in the soil. You can use the legume as feed or as green manure, depending on the situation.

In semi-arid areas, you can sow legumes into natural pastures, then cut them to make hay after the rainy season.

Some farmers grow plots of fodder near their homestead, for use as "fodder bank" during shortages. Others make hay or silage, or harvest some of the leaves from crops. For example, after silking of maize cobs, the lower leaves of maize can be harvested as a feed.

► *Box 9.2* describes how one farmer has improved his pastures, livestock feeding and management, and is helping other farmers do the same.

► *Exercise 9.6 Improving fodder management and use.*

► *Exercise 9.7 Making silage.*

► *Exercise 9.8 Making hay.*

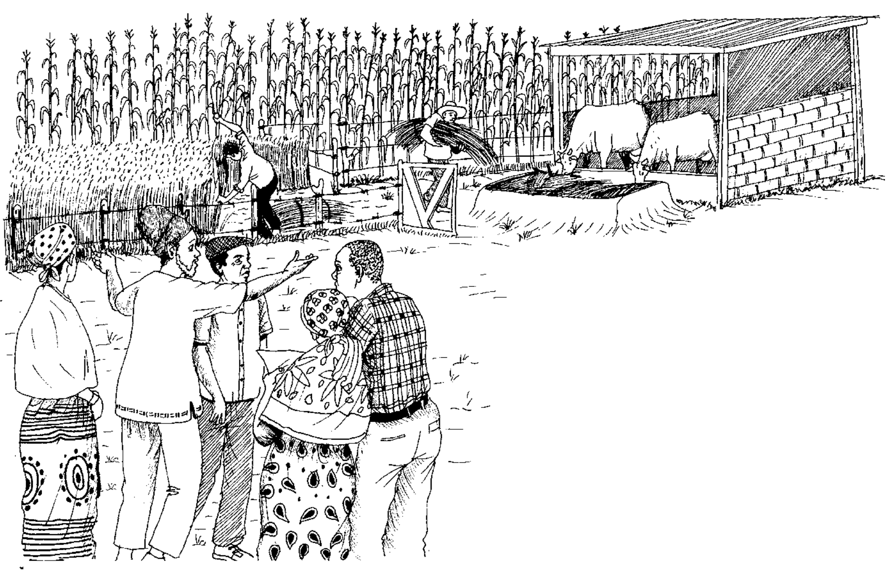

Figure 9.5. Have the right mix of livestock, crops and fodder

Pastures and forage

Like other crops, pastures and fodder crops can continue to be productive only if the nutrients taken out through grazing and harvesting are returned to the soil in one way or another. This is especially true on poorer soils. It is necessary to find a balance between intensification (increasing productivity per unit area of land and water) and sustainability.

- Cutting young grass frequently can improve animal production and manure quality. But it extracts more nutrients – which must be subsequently returned to the soil to maintain production.
- Letting animals graze too much on the same area, or cutting too much of the vegetation, can damage the soil fertility and lead to compaction, increased runoff and erosion.

Growing suitable (multi-purpose) legumes can provide extra nitrogen for the soil and protein for animals. They can be grown either as pure stands or intercropped with crops or grasses. In a way, this improved forage provides a double benefit: it provides a healthy feed for the animals, and it results in better manure that can be used to feed the soil.

Fodder quality

You can tell a lot about a fodder plant by looking at it, feeling it and even tasting it. In general, a plant that makes good fodder also breaks down quickly in the soil.

► *Box 9.2.*

► *Exercise 9.2 Fodder plants.*

Box 9.2. How good is your fodder?

Dark green leaves mean the plant is high in nitrogen and protein. That means it is nutritious (so makes good feed), and will decompose quickly in the soil.

Yellowish leaves mean the plant is low in nitrogen and protein.

Soft, young leaves that you can tear easily are low in fibre. They are easy for animals to digest, and will decompose quickly in the soil.

Tough, woody stems and older leaves are high in fibre. They are hard to digest, and break down slowly in the soil.

An astringent (bitter) taste means the plant will be hard to digest and will break down slowly in the soil.

Hairs and thorns mean poor forage – as animals generally do not like to eat them.

Using crop residues

Straw and other crop residues are a major source of livestock feed, but they are also important for soil fertility. Should you give them to your animals, or should you leave them in the field (or make compost) to improve the soil?

Some guidelines:

- You can increase the amount of vegetation that is produced, so there is more available for animal feed and soil organic matter.
- You can use the poorer parts of the plants – such as maize stover, older grass stems and woody tree cuttings – to improve the soil. Use the younger, nutritious stalks and leaves as feed.
- Use fodder that animals refuse to eat as livestock bedding, as mulch, or to make compost. ► *Table 7.4* for the nutrient value of various forage crops.
- Make sure you return as many materials as possible to the fields – old bedding, manure, compost, and so on.

► *Exercise 9.3 Bedding materials.*

Growing fodder crops

Cover crops, green manures and grass strips or bunds help conserve soil and water (► *Module 5 Using organic materials*). They can also be a good source of livestock feed. You can also grow small plots of grasses especially for fodder.

You can grow more, and better, fodder by planting more productive types of grasses and legumes. That will produce stronger, healthier animals; it will

Box 9.3. Conservation of pastures in semi-arid Kiserian

Kisioky Sambweti is one of a few farmers in Kiserian who are trying something new – keeping fewer cattle, and conserving pastures for grazing during the dry season.

Kiserian is a village in Arumeru district, northern Tanzania. Farmers there grow mixed crops and keep free-range cattle. There is not much rain – just 500 mm a year, which falls mainly in a short rainy season between March and May. August to February are very dry months, and many farmers migrate to neighbouring regions in search of pastures and water for their cattle.

Kisioky divided his land into several pasture blocks. He planted legume grasses and trees in the natural pastures, and multipurpose legume trees and improved grass around the edges of his crop fields. He lets his cattle graze each paddock in rotation during the rainy season, and also gives them fodder from planted pastures and the field edges. He uses some paddocks to make hay, some of which he sells to neighbours. He leaves other paddocks uncut so they can be grazed during the dry season. After harvest, he collects and bales bean stover to feed in the dry season.

Using these methods, Kisioky has enough pasture to feed his animals all year round. He keeps two adult crossbred animals and one of a local breed, along with one or more heifers. Sometimes his neighbours try to graze their animals on his pastures, so he has to keep watch during the night.

Kisioky's success has been recognized by the Project on People, Land Management and Ecosystem Conservation. He now trains other farmers how to avoid the need to migrate in the dry season by keeping fewer cattle and by conserving and improving their pastures.

also improve the soil and produce better quality manure that can be used to improve the soil further.

More on cover crops in ► *Module 8 Conservation agriculture*.

Growing fodder trees

Some types of trees are also a good source of livestock feed. If you plant trees, choose the type of tree carefully. Choose types that grow well in your area, are leguminous (i.e., they fix nitrogen in the soil), have deep roots (so they can tap water and nutrients from deep down and do not interfere with crops) and produce a lot of nutritious leaves and fruits or pods.

Trees have many other uses too – they produce wood for building or fuel, yield fruit to eat or sell, provide shade for people and animals, and protect the soil from wind and water erosion.

You can plant trees in many places – around fields, along paths and roads, within crop fields or pastures, and on wasteland. You can also set aside plots to use as an orchard or woodlot. Or you can plant them in field lines, along the contour if there is a slope; this is called "alley cropping". Prune the trees regularly and feed some of the leaves to animals; use the rest of the leaves and twigs as mulch. Make sure to spread the manure back on the land to raise the level of organic matter in the soil. You may have to apply phosphorus fertilizer to make sure leguminous trees grow well.

Leguminous fodder trees produce good livestock feed, especially when other types of fodder are scarce. Leaves from these trees can make up about 20% of the feed you give to your animals. They are useful in particular for demanding animals such as calves and dairy cows.

The best-known fodder species include *Leucaena, Sesbania* and *Calliandra*.

Box 9.4. Rehabilitating a degraded farm in Uganda

When Katumba Henry took over his 5-acre farm in Kkona village, Lukwanga Parish, in central Uganda, it was overworked and degraded. Hardly anything would grow except local bananas, used for making the local beer. Even they produced little.

What could Katumba do? He started attending training sessions on sustainable agriculture, and learned a range of techniques to manage his soil and water better. He learned how to stabilize bunds with Napier grass; grow leguminous trees such as *Calliandra*, *Leucaena* and *Sesbania*, and cover crops such as *Dolichos lablab*, *Canavalia* and *Mucuna*; manage animals as an integral part of his farm; manage soil nutrients through composting, liquid manure and mulch; plant intercrops of legumes such as beans, pigeonpeas and groundnuts; and harvest and recycle water.

Katumba now keeps cattle, pigs, poultry and goats, and grows coffee, bananas, beans, upland yams, fruit trees, sweet potatoes, cassava and maize. Through better soil management over the last 4 years, he has seen his farm's productivity rise. He now harvests bunches of bananas weighing 110 kg (for the hybrid FHIA 17 variety) and 60 kg (for the local variety), local yams 33 kg, and three bags of beans from a quarter-acre plot.

How can he produce such yields? Katumba says it's because he feeds his soil. His eight member family now has enough to eat, and he and his wife have started a community organization to teach other farmers in the area how to do the same.

- ***Calliandra*** has deep roots and can grow on poorer soils. *Calliandra* has to be fed fresh: 3 kg of fresh Calliandra leaves can replace about 1 kg of dairy meal.
- You can dry ***Sesbania*** and ***Leucaena*** leaves by spreading them on black plastic, then put them in bags to store them for feeding later. Sesbania can serve as an improved fallow. Sesbania and Leucaena leaves can also be dried for hay.
- ***Leucaena*** and ***Prosopis*** can be hard to control: make sure they do not spread and become invasive weeds.

You can also encourage the farmer field school members to think of types of trees that grow in the area which might be used for feed and other uses around the farm. If they are interested to try alley cropping, they should think of the extra work needed to keep the trees pruned, as well as the risk of the trees competing with the crops for light and water.

► *Box 9.3* shows how one farmer in central Uganda has restored a degraded farm by raising crops, animals and trees.

► *Exercise 9.9 Fodder trees.*

Conserving fodder

You can conserve fodder in various ways. Two of the most common forms are as silage and as hay.

Silage

Silage is moist fodder that is fermented and stored in an airtight place. It can be made from maize, forage grasses, legumes, wheat and lucerne, or from natural grasses. Silage is made from the whole plant, not just the grain. The best silage is made from young plants because these are rich in protein and are easy for animals to digest.

The plants should be moist but not too wet: they should be allowed to wilt before putting them in the silage pit. If no moisture comes out of a plant when you screw it with your hands, it is dry enough (this is about 30% moisture content).

Chopping up coarse material (such as maize stalks) and adding molasses also makes good silage.

It is important to keep the silage airtight. That means packing it well and covering it with plastic (weighted down with soil) to keep the air out. That allows it to ferment properly.

► *Exercise 9.7 Making silage.*

The longer the storage time and higher the temperatures, the more likely the silage will be poor quality because it is mouldy. If fermentation was not complete, it may become spoiled. Rats and mice may make holes in the plastic sheeting, so keep the storage area clear of vegetation where they might hide. Keep a cat to hunt the mice! After opening the silage and letting in air, use it fairly soon, i.e. within 1 week if it is hot, and 2–4 weeks if the weather is cool. Livestock will usually eat mouldy silage, but if it is too mouldy they may get lung irritations.

- A white mould or yeast is very common, and animals will eat the feed without problems.
- A grey-blue mould (*Aspargillus*) may aggravate allergies or cause abortions in cattle.
- A red or pink mould (*Fusarium*) may make animals refuse to eat, or cause them to vomit. It can also cause reproduction problems.

Hay

Making hay is a simple way to conserve surplus fodder. Hay is grass or other plants that have been dried. You can make it from crop residues such as rice or maize stalks, legumes or natural grasses. Cut the grass before when it is about 6–8 weeks old, before it flowers. That produces hay that is rich in protein and is easy for animals to digest. It may be possible to take more than one cutting in a season.

Allow the cut grass and other plants to dry quickly in the field or on black plastic sheets. Small, soft leaves (like those from fodder trees) may dry in one day; coarse grasses like Napier grass may take 5 sunny days or more to dry enough. Chop up coarser stalks so they dry faster. Turn the material over so it dries evenly throughout.

► *Exercise 9.8 Making hay.*

Exercise 9.1 Looking at crops and livestock

Livestock can be kept in many different ways: communal grazing, intensive grazing and stall feeding are examples. How they are kept depends on many things – the local climate and soils, how much land is available, who can look after them, and whether farmers can sell products such as meat, milk and eggs. Farmers can keep different numbers and types of animals, choose different mixes of livestock and crops, and use crop residues and manure in different ways.

This exercise gives participants a chance to look at various ways of keeping animals and how the animals relate to other parts of the farm.

Learning objective

Understand how the soil, crops and livestock relate to each other.

Identify problems and opportunities to overcome them.

Timing

At any time when you see opportunities to improve the integration of crops and livestock.

Preparation

Organize a discussion on the links between the soil, crops and livestock.

Suggest different types of farms as examples of how crops and livestock relate to each other. The participants can then suggest 2–4 such farms. These may have been identified during the transect walk (► *Exercise 2.2*).

Duration

2 hours.

Materials

Cards, marker pens.

Steps

1. Explain the focus of the exercise – i.e. to look at how the soil, crops and livestock relate to each other.
2. Ask the participants to brainstorm how the soil, crops and livestock relate to each other.
3. Divide the participants into smaller groups of 4 or 5.
4. Ask each subgroup to visits one or more farms and note the soil-crop-livestock links on cards. Ask the subgroups to classify each of the links as a strength, a weakness, an opportunity or a threat:

- A **Strength** is where the farmer is doing something that benefits the soil (or a crop or animal) (e.g., the farmer collects manure and uses it to fertilize the soil).
- A **Weakness** is where the farmer is doing something that does not benefit the soil (or crop or animal) (e.g., the farmer burns the dung instead of using it as manure).
- An **Opportunity** is a way the farmer could improve the farm management (e.g., the farmer could use some waste land to grow fodder).
- A **Threat** is something that prevents the farmer from improving management (e.g., animals are traditionally allowed to graze anywhere).

5. Ask each group to report on their findings to all the participants.
6. Follow this with a plenary discussion focusing on the strengths and weaknesses, opportunities and threats.
7. Invite the participants to discuss ways of improving each of the farms they have reported on.
8. After the discussion, you can organize visits to farms where farmers have found good ways to manage animals, crops and the soil.

Keep the cards for future reference and to check the knowledge that participants gain during the farmer field school.

Questions to stimulate discussion

- How do the soil, crops and livestock affect each other? In what ways can one benefit from another? In what ways do they compete or conflict?
- Why do farmers keep different types of livestock? What are the various uses and values of different types of animals?
- How much land do farmers devote to crops, and how much to animals? On the farms visited, and in the area in general?

- What has changed over recent years? In the supply of forage, condition of pastures and livestock, from season to season and from place to place?
- How important are pastures or forage crops on the farm – as feed, as part of crop rotations, and for soil productivity?
- Which forages are useful in your own farm? In the farms you have visited? What are your experiences with various types of legumes (grain, forage, tree, green manure)?
- What benefits might you expect from legumes on land that is not intensively used?
- How do different farmers kraal or house their animals? What are the advantages and disadvantages of the various ways?
- How do different farmers handle manure? What do they do at different times of year? When and how do they collect, store, process, and apply the manure? What problems do they face? How could they do things better?
- Do farmers give their animals supplements such as oilseed cake, bran or licks? Why do they do so? Do these supplements affect the manure quality and soil productivity?
- Are there enough people to do the work needed to grow forage, and to feed and care for livestock? Who does this work – men, women, or children?
- What work do the animals do – for example, pulling ploughs or carts? How important is this?

Exercise 9.2 Fodder plants

This exercise enables farmers to compare various fodder plants and to see which make good livestock feed.

Learning objective

Understand the characteristics of different fodder plants.

Understand how different feeds affect animals, manure and soil fertility.

Timing

When discussing ways to improve livestock management.

Preparation

Identify and collect suitable fodder plants – either beforehand or during the exercise itself.

Duration

2 hours.

Materials

Examples of various types of fodder plants, cards, pencils.

Steps

1. Collect different fodder plants – as many different types as possible.
2. Explain that you can tell a lot about a fodder plant by looking at it, feeling it, and even tasting it. You can tell how good it is as livestock feed or to enrich the soil, for example, if you use it as mulch or to make compost. ► *Module 5 Using organic materials.*
3. Divide the participants into smaller groups of 4–5 people each.
4. Give each group several different types of fodder plants, and ask them to describe them. They should use their eyes, hands, noses, and tongues! They may have to strip green leaves, dead leaves and stems to make a good judgement. For each plant, ask them also to note how common the plant is, the effect it has on animals, manure and the soil.
5. Ask each group to report back to the plenary. Facilitate a discussion of what they have learned.
6. Ask the participants to rank the various fodder plants based on (for example) suitability as feed, usefulness as mulch, and so on. Keep the results for later use so the participants can identify improvements, such as improved mixtures of feed.

Questions to stimulate discussion

- What are important differences between the plants?
- Which characteristics are important for animal nutrition, manure quality and soil improvement?
- Do any feeds have special properties? For example, can they be used to control tapeworms or other pests and parasites? (Feeds are not just for nutrition!)
- Which feeds supply a lot of water to animals?
- What is the difference between various parts of the plants? Do you use different parts for different purposes – such as using stalks as mulch and leaves as feed?

Exercise 9.3 Bedding materials

Learning objective

Understand the effects of different bedding materials on animals and manure.

Timing

When discussing livestock or composting.

Preparation

Identify several farms that use different types of bedding materials.

Collect some manure and various materials used for bedding (for the optional demonstration).

Duration

2 hours.

Materials

Notepaper, pencils.

For the optional demonstration: several different types of materials used for bedding: straw, maize stover, sawdust, leaves, coarse and finer materials; bucket of water (to represent urine).

Bedding materials soak up dung and urine, and make good organic fertilizers when added to the soil. But not all bedding materials are the same. This exercise lets participants look at various types of bedding and helps them decide the advantages and disadvantages of each type.

Steps

1. Explain that the group is going to look at different bedding materials and examine how good they are for use as bedding and afterwards to enrich the soil.
2. Divide the participants in subgroups of 4–5 people.
3. Ask each subgroup to visit one or more of the farms and look at how they use the bedding materials. Each group should note the type of material used, its characteristics (dry/moist, coarse/fine, ability to soak up urine, etc.), and how suitable it is as animal bedding and for adding to the soil after use. They should look at both fresh and used bedding. Each group may be able to look at 3–5 types of bedding.
4. Bring the groups back together to discuss what they have seen. Ask the participants to group the materials according to the characteristics they have noted. This discussion may lead the group to decide to test various materials to see which is the best.
5. **Optional demonstration.** Good bedding soaks up a lot of urine, which is rich in nitrogen. You can check what types of bedding soak up the most urine by mixing a set amount of water (say, 2 litres) with piles of different types of bedding materials. Observe how much of the water is absorbed by the bedding, and how much runs into the ground underneath.

Questions to stimulate discussion

- What are good materials for animal bedding? For use as organic fertilizers afterwards?
- Which characteristics are important for animals? For soaking up urine, producing good manure, and making good compost?
- How much moisture can the bedding soak up? What happens to urine that is not soaked up?
- Are there differences between dry and wet bedding, and between coarse and fine materials – for example, between maize stover and dry leaves? Do you know other materials that might be suitable for bedding?
- What happens if rain gets into the bedding material and manure?

Exercise 9.4 Different types of manure

Manure varies widely in quality. Manure from well-fed animals has more nutrients than from hungry animals. Poultry droppings, cattle dung and goat faeces look different, and they contain different amounts of nutrients. This exercise helps farmers recognize the uses of different types of manure and enables them to test how well they help crops grow.

Steps

1. Collect manure from various types of animals – well-fed cattle, poorly fed cattle, goats, chickens, etc.
2. Ask the participants to identify criteria for evaluating the manure: colour, consistency, fibre content, weight, fineness, smell, and so on.
3. Divide participants in subgroups of 4–5 people.
4. Ask each group to evaluate the manure samples and to note the criteria of each sample. What colour is it? How much fibre does it contain?
5. Bring the group back together to discuss what they have learned. Group the manures according to how quickly they release nutrients and how suitable they are for different crops.

Pot or plot trial

6. Select several types of manure to test in a small experiment (► *Exercise 7.4 Studying limiting nutrients*). You can use small plots (one for each type of manure), or pots or buckets (one or two for each type of manure). Make sure you leave one small plot without any manure as a comparison. Instead of different types of manure, you can also use different amounts of manure.
7. If you use pots or buckets filled with soil, plant four seeds in each pot. Thin them to two plants after they germinate. Add water to keep the soil moist.
8. Each week, check the plant colour, height, stem thickness and leaf size, and check for any nutrient deficiencies.
9. Discuss what the participants have seen, and reach conclusions about the usefulness of the different manures.

Questions to stimulate discussion

- What differences are there between poultry droppings, cattle dung, and goat faeces? Which is best for the soil? Which is easiest to collect?

Learning objectives

Recognize the differences between manure from various types of animals.

Identify easy ways to handle manure.

Identify indicators for effects on crop growth.

Timing

When utilization of different manure types can be improved.

Preparation

Work out how much manure it is realistic to apply in the field, and then how much to use in the pot experiment (► *Module 3*).

Collect samples of manure from different types of animals, as well as manure that has been handled in different ways.

Duration

About 2 hours for characterization and planting a quick trial. Monitor the experiment during a few subsequent farmer field school sessions.

Materials

Samples of manure from various types of animals and ways of handling manure.

Several buckets or planting pots (or a plot that can be subdivided into several smaller plots), watering can, soil from a field with relatively low fertility, seed of maize or other crop that grows quickly, notepaper, pencils.

Exercise 9.5 Manure at different times of year

Learning objectives

Understand how feeding and manure handling differs during the rainy and dry seasons.

Identify ways to improve manure handling.

Timing

When manure handling is being discussed. At least two sessions needed – one in the wet season, and one in the dry season.

Preparation

Select several farms to visit that handle manure in different ways.

Duration

Visits to farms during different seasons: about 1 hour per visit.

1 hour for final plenary discussion.

Materials

Notepaper, pencils.

The amount and quality of manure can vary tremendously during the rainy and dry seasons. Rainy season manure is generally wetter and better; it is heavy, so farmers may prefer to apply it to fields close to home. Dry season manure is coarser and drier, and easier to carry to fields further away.

Because manure is heavy, farmers may want to use it on high-value crops close to the homestead.

This exercise helps farmers to see the differences between the rainy and dry seasons, and invites them to think of ways to improve manure handling.

Steps

1. Introduce the farms to visit, and ask participants for more suggestions.
2. Discuss what things to look for in the manure – such as the colour and consistency of the manure, its age, whether it is protected from the sun and rain, etc.
3. Divide the participants into smaller groups of 4–5 people.
4. Ask each group to visit one of the farms and note what they see.
5. Bring the groups back together and discuss what they have seen. Ask them how the farmers might improve their handling of the manure.
6. Repeat the exercise during the next season and discuss the differences the participants have observed.

Questions to stimulate discussion

- How does the season affect the quality of the manure?
- Do you manage manure differently in the wet and dry seasons? How about the manure from different feeding practices, or from different types of animals?

Exercise 9.6 Improving fodder management and use

There are many ways to manage fodder – by managing grazing, protecting certain areas, planting grasses and legumes, growing fodder trees, making hay and silage, and so on. It is especially important to make sure there is enough available during the dry season when fodder often goes short. This exercise helps farmers identify ways to grow more fodder and improve how they manage it.

This is a useful exercise if fodder supply is a problem in the area.

Learning objective

Identify problems in fodder production and ways to overcome them.

Timing

After discussing fodder plants (► *Exercise 9.2*).

Preparation

Identify farms with innovative ways to manage and use fodder.

Duration

About 2 hours.

Materials

Notepaper, pencils.

Steps

1. Arrange visits to farmers who have improved the way they grow and manage fodder. Or invite a forage or livestock specialist to present examples of improved practices.
2. Ask the participants how the amount of pasture and fodder crops have changed in the past. Is there more pasture and fodder available now, or less? How about the quality of fodder? What effects have these had on the soil fertility, livestock productivity and amount of manure?
3. Divide the participants into smaller groups of 4–5 people.
4. Ask each group to draw up a seasonal calendar (► *Exercise 2.3*) showing the availability of fodder. Ask them to think of ways to improve the amount and quality of fodder (when and where to grow it, how to manage it, whether to set aside certain areas as pasture, what species to use, etc.).
5. Facilitate a whole-group discussion on how to manage existing types of fodder better, and the possibility of introducing improved forages such as lablab, vetch and Mucuna.
6. Ask the small groups to think of where these improved forages could be drawn. Ask them to draw a map of suitable locations.
7. Again with all the participants, discuss the possibility of trying out improved fodder management. If appropriate, design a test of several different forage types, or of ways to manage fodder better.

Questions to stimulate discussion

- What has changed in how you manage and use fodder during the past years? Why?
- Have you tried improved forages? Which types? What did you think of them?
- What legumes can be used as fodder? Under what conditions (on what types of soil, where to plant them, how much work do they take, etc.)?
- What do you expect from improved management of forages (manure, cutting)?
- How can you make more fodder available during the dry season? For example, by planting fodder plots, fodder trees, preventing grazing on certain areas, or making hay or silage?

Exercise 9.7 Making silage

Learning objectives

Make good silage.

Understand the importance of fodder conservation.

Timing

When plants are available to make silage – probably in the middle of the rainy season.

Preparation

Identify a pasture that can be cut (it may be sown specially, or protected from grazing so it can be used for silage).

Duration

For preparations, 2 days.

For silo filling, 4 hours.

Materials

Grass and legumes cut from pasture, spades, sheet of plastic to cover the silo, bean chaff; large barrel, partly filled with water.

Adapted from

FAO (2002)

Silage is a good-quality animal feed, but must be made properly. This exercise shows farmers how.

Steps

1. Dig a silo pit on a gentle slope (3–4% slope) measuring 2m wide, 3m long and 2m deep. Dig a channel around the pit to stop rainwater from flowing into it.
2. One day before you plan to fill the silo, cut the pasture and leave it to dry. After a few hours, turn the cut the vegetation so it dries evenly.
3. Carry the wilted vegetation to the silo pit, and put it into the pit so it is packed tightly. Use the water barrel to compact each layer of vegetation, or trample it hard to squeeze the air out.
4. Line the sides of the pit with bean chaff (this helps prevent undesirable micro-organisms from growing).
5. When the pit is full, cover it with the plastic sheet. Put a layer of soil on top of the sheet to keep the air out.
6. Leave the silage to ferment for several weeks. The silage can be stored for months or even years if made of good quality materials. But once the pit has been opened, or the plastic sheet damaged, only a few weeks' storage time is possible as the silage will rapidly deteriorate.
7. When you need to feed your animals, open the silo and take out as much of the silage as you need. The silage should be smell sweet. Cover the rest of the silo with plastic again and push it down with soil until you need some more.

Questions to stimulate discussion

- How do you conserve fodder for use during the dry season?
- What are the best types of plants for silage? Why?
- What other ways can you feed animals in the dry season?

Notes

For more information, ► www.kari.org/InfoBrochures/Silagedryseason.htm

Exercise 9.8 Making hay

Hay is easy and cheap to make. It is easiest to store if it is in bales. This exercise shows farmers how to make and bale hay.

Steps

1. Make a wooden box, 0.75 x 0.8 x 0.3m. This should be strong but light (so it is easy to carry around). To save weight, the sides can be made of slats of wood with gaps in between.
2. Cut the pasture and leave the cut plants to dry in the sun. Turn the cut plants so it dries all the way through. Put it in rows to make it easier to turn and to collect. Usually, in the tropics, plants cut during the morning and left in the sun during the day will be dry enough for hay making in the afternoon. The leaves are dry enough when they break and crackle when you squeeze them.
3. Cut several pieces of string, long enough to go around the bale. Lay them in the box so the ends hang over the sides and can be tied together around the bale.
4. Collect the dried vegetation and pack it into the box, on top of the string. Pack it down as tightly as possible to make a compact bale.
5. When the box is full, tie the ends of the string together to hold the bale together. Remove the bale from the box, and store it in a dry place until it is needed for feeding to animals.

Questions to stimulate discussion

- How do you conserve fodder for use during the dry season?
- What are the best types of plants for hay? Why?
- What other ways can you feed animals in the dry season?

Notes

For more information, ► www.kari.org/InfoBrochures/Makehay.htm

Learning objectives

Make good hay.

Make a baling box.

Understand the importance of fodder conservation.

Timing

When plants are available to make hay – in the middle of the rainy season.

Preparation

Make a wooden baling box (► Step 1).

Identify a pasture with grass and legumes that can be cut (it may be sown specially, or protected from grazing so it can be used for hay making).

Duration

1 day to make the baling box.

2 hours for cutting grass and legumes.

1 hour for making hay bales.

Materials

Grass and legumes cut from pasture (or rice stalks after harvest), wood to make baling box, hammer, nails, strong string or twine for baling.

Adapted from

FAO (2002)

Exercise 9.9 Fodder trees

Learning objective

Understand the benefits of leguminous trees.

Recognize how to plant leguminous trees without giving up too much cropland.

Timing

When you are discussing livestock feeding or agroforestry.

Preparation

Identify farmers who use various types of trees for fodder, and arrange visits to their farms.

Duration

About 2 hours (visits may take longer).

Materials

Leaves from various fodder trees (you can collect these during the visits), large sheets of paper, marker pens.

Steps

1. Start with visits to several farmers who use fodder trees.
2. Facilitate a discussion on the farmers' experiences with fodder trees. Ask them to highlight the benefits and problems with trees and their use as fodder.
3. Divide the participants into small groups of 4–5 people.
4. Ask each group to choose a farm belonging to one of the group members. Ask them to draw a map of the farm, showing where fodder trees might be grown. What are suitable locations, what sort of trees could be planted, and how might the trees be used?
5. Ask each group to report back to the plenary. Discuss whether any of the participants want to try out planting fodder trees.

Questions to stimulate discussion

- Have you tried planting or using fodder trees? What have your experiences been?
- How do you think these trees might benefit your farm?
- Where and when would you include fodder trees in your farm?
- Do the trees compete with crops for water during the dry seasons? How can you avoid this?
- Which tree legumes can be used on fallow land?

Module 10. Managing rainwater

If you do not have irrigation, your crops, livestock and even your family probably depend on rainfall. But in many areas, rain falls in short, heavy storms, and most of the water runs off the land and directly into rivers and streams, often carrying precious topsoil and nutrients away with it. The rest of the year is dry, and the streams, springs and even wells may dry out. Crops, animals and people may go thirsty unless there is a permanent, reliable water source or water can the villagers can collect and store.

With good water management, farmers may be able to double, or even quadruple, their yields! How can they do this? How can they manage water better? How can they make sure there is enough water for their crops and animals, even though the rainfall is unreliable?

This and the next two modules focus on semi-arid and sub-humid areas where smallholder farmers face the constant risk of drought. They aim to help farmers make effective use of every drop of water. This module focuses on what happens to water in the field, and how to increase the amount of water held in the soil. The next two modules deal with water harvesting: ► *Module 11* addresses water harvesting for crops, while ► *Module 12* discusses how to harvest water for people and animals.

Learning objectives

After studying this module, you should be able to:

Understand what happens to rainwater in the field.

Understand how crops use water.

Recognize if a crop is short of water, or has been in the past.

Manage your soil to cut water losses, increase the amount of water that soaks into the soil, and increase the amount that the soil can hold.

Understanding water

Most smallholder farmers do not make the best use of the rainfall. In general, crops use less than 30% of the water falling as rain. The rest evaporates from bare soil, runs off, and sinks down so deep into the soil that crop roots cannot reach it (► *Figures 10.3* and *10.4*).

These losses are highest on slopes and on unhealthy soils with little organic matter and poor cover (► *Figure 10.2*).

Farmers can do a lot to improve how they manage soil moisture in the field. What they do depends on the type and size of farm they run, the local situation, and how much labour and equipment they have.

Farmers often say they need irrigation. But irrigation takes a long time to set up, and is difficult and expensive. It may not be the best solution, and in many places it is unrealistic. Here are some alternatives that make the best use of every drop of rainwater:

- Match the available water with crop and livestock needs.
- Minimize runoff: capture water, and make sure it soaks into the soil and stays there.
- Capture water and bring it to where it is needed most.
- Avoid waterlogging and flooding during heavy rains.

Doing these things can reduce the risk of drought harming crops and animals, and will raise yields and make them more reliable.

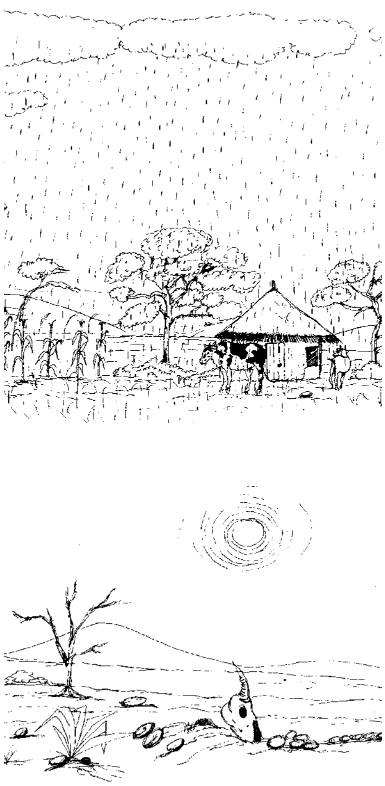

Figure 10.1. We cannot control the weather. But we can manage rainwater!

What happens to rainwater?

When rain falls on the ground, various things can happen to it (► *Figure 10.3*):

10

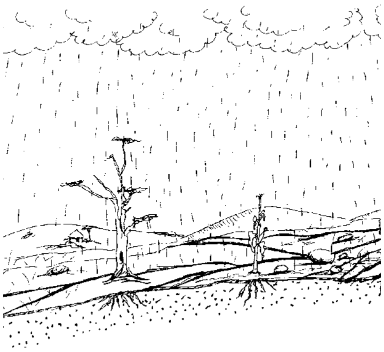

Figure 10.2. A field with poor crop cover.

Heavy rain pounds the bare soil, sealing the surface. The water has little chance to sink into the ground, so most of it runs off, leaving thirsty crops.

- Some of the rain soaks into the ground. It seeps into the soil through cracks and tiny holes. The soil holds onto some of this water, and the roots of crops and other plants can use it. The rest drains further down through the soil into the groundwater, and some of this fills wells, springs and rivers. This is known as **infiltration** (► *Box 10.1*).
- Some of the water flows off downhill (called **surface runoff**) and finds its way into rivers, lakes and dams. From there it may also sink into the ground and fill wells.
- The rest evaporates from the surface.

► *Exercise 10.1 The water cycle.*

Questions to stimulate discussion

Encourage participants to think of why crops use less than 30% of the water that falls as rain. Some questions:

- What affects the amount of water that soaks into the soil? (Hint: rainfall amount and intensity; bare, compacted soil surface; soil type; amount of organic matter; slope, etc.)
- What affects the amount of water roots can take up? (Hint: hardpan, soil type, type and depth of roots, age of crop, etc.)
- What affects the amount that leaves lose into the air? (Hint: type of crop, temperature, humidity, age of crop, etc.)
- How is water lost from a field?
- How much water evaporates from bare soil, or runs off downhill?

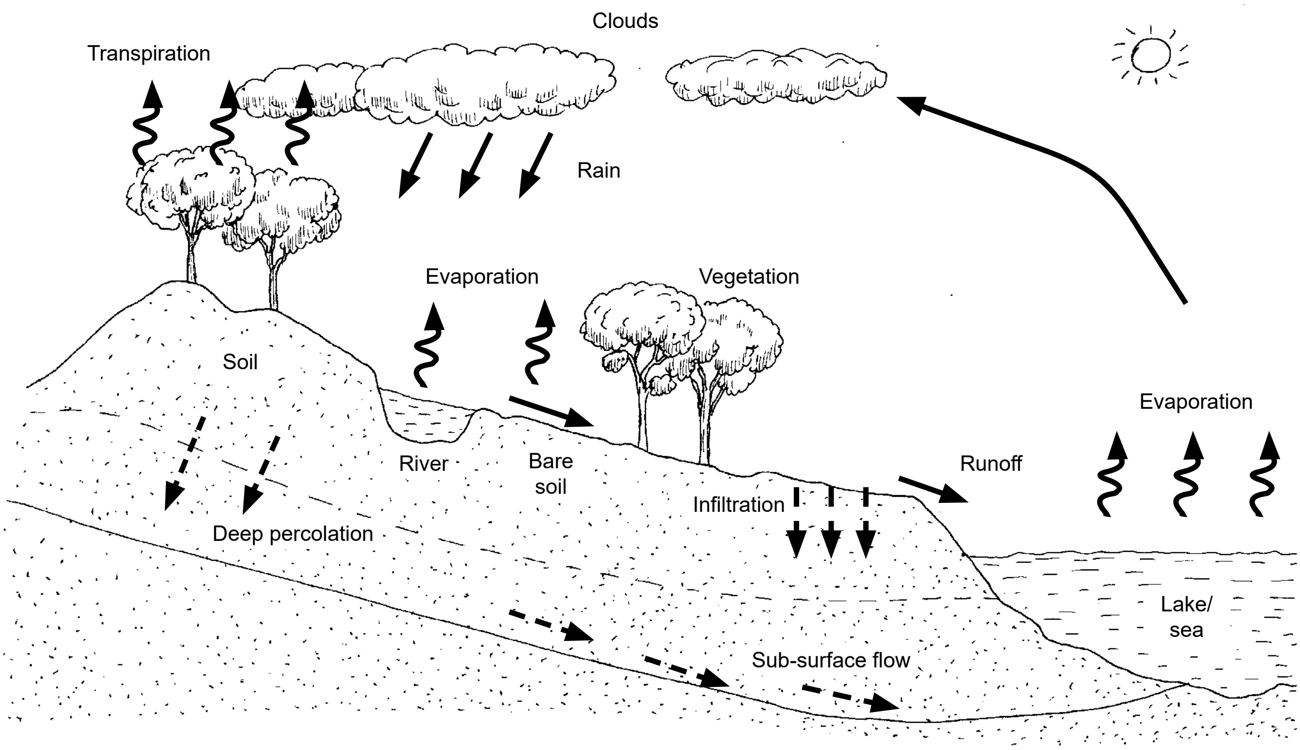

Figure 10.3. The water cycle

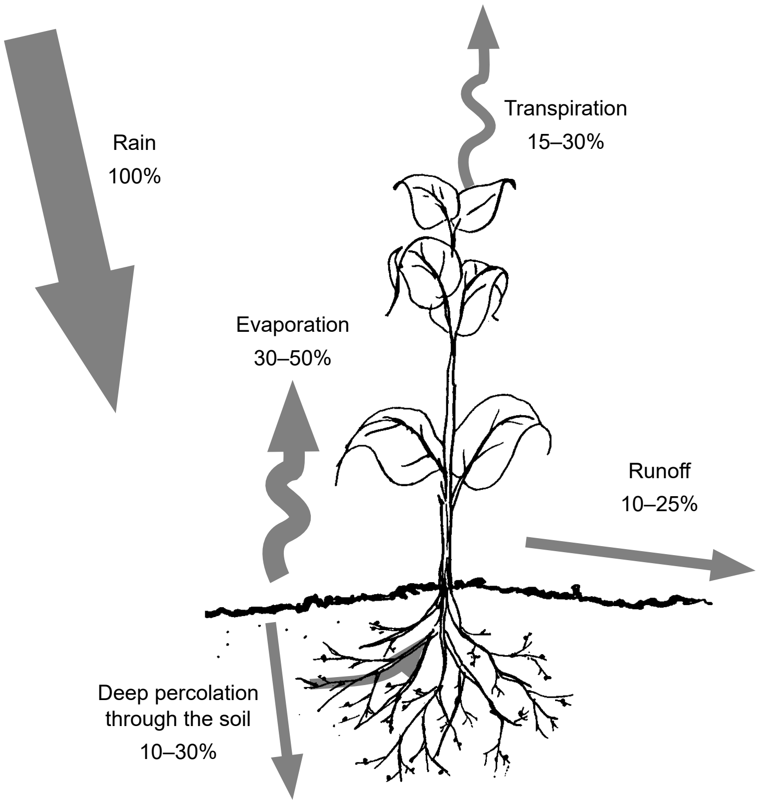

Figure 10.4. What happens to rainwater?

Box 10.1. Water words

Precipitation. Water that reaches the ground from the air: rain, drizzle, dew, snow and hail

Infiltration. Water that soaks into the soil

Transpiration. Water that plants take up through their roots, then lose from their leaves into the air

Evaporation. Water that disappears into the air from lakes and rivers, and from puddles or the soil that dry out in the sun

Surface runoff. Water that does not soak into the ground but flows away downhill

Permeability. The soil's ability to let water pass through it

Find out what farmers know about the weather

Local people usually know a lot about weather patterns in their area. They have ways to predict when it will rain, and have found ways to conserve water and deal with drought. Try to build on this rich store of knowledge!

Rainfall

In arid and semi-arid areas, most rain falls in a few short, sharp showers. These showers are hard to predict. One place may be soaked while the neighbouring village is bone-dry. One year may have a lot of rain, while another year may mean months without rain. Farmers have to deal with water shortages and drought.

Wetter areas may still have dry spells and flooding. Farms may experience drought because not enough water soaks into the soil when it rains. The water may instead run off downhill and flood low-lying areas.

What happens during heavy rain? Heavy raindrops pound bare soil, forming a hard crust that stops water from soaking into the soil. If the rain falls too fast for the soil to take it up, it runs off downhill. It carries loose soil and nutrients with it. This is **erosion**.

Farmers can influence this by how they manage their soil. They can increase the amount of water that soaks into the soil in various ways. More water in

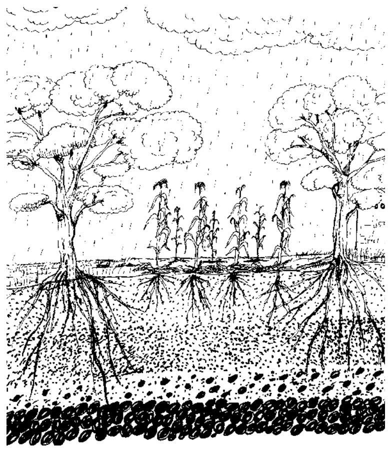

Figure 10.5. A field with good soil cover.

This field has good soil cover that protects the soil and slows water down, letting it sink into the ground. Trees and healthy crops have deep roots that tap water deep in the soil. There is no runoff from the field, even during heavy rain.

the soil means crops can withstand drought better, and also reduces flooding and erosion.

Measuring rainfall

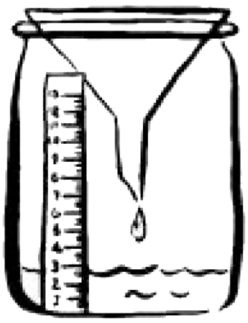

Figure 10.6. Homemade rain gauge

Understanding the rainfall pattern will help farmers plan what crops to plant, and when and where to plant them. You can use a rain gauge to measure and record the amount of rain that falls.

Set up several rain gauges at different places in the community to see how the rainfall varies from place to place.

If you cannot get a standard rain gauge, you can use a straight-sided pot (such as an aluminium saucepan). Put it on a level surface, raised above the ground (e.g., on some stones) so water does not splash into it, and the wind, animals and children do not knock it over. After each time it rains, measure the depth of water (in millimetres) in the pot with a ruler. Note the measurement on the form in ► *Figure 10.6*. Then empty the pot, clean it if necessary, and put it back.

Keep a record for several years so you know how much rain to expect, and when to expect it.

► *Exercise 2.3 Seasonal calendar* (with emphasis on rainfall).

Table 10.1. Example of form to record rainfall

Location: Year: Month:							
Date Rainfall (mm)	1	2	3	4	5	6	7
Date Rainfall (mm)	8	9	10	11	12	13	14
Date Rainfall (mm)	15	16	17	18	19	20	21
Date Rainfall (mm)	22	23	24	25	26	27	28
Date Rainfall (mm)	29	30	31	**Total**			

Evaporation

What happens when a bowl of water is left in the sun? The water will disappear into the air, eventually leaving the bowl dry. This is called **evaporation**. In the same way, water evaporates from the soil, plants, puddles and lakes, and from droplets on leaves after the rain.

How quickly the water evaporates depends on:

- The weather: the sun, the temperature, the air humidity, and wind
- The roughness of the soil and soil cover
- The cropping pattern and stage of crop growth.

Water evaporates quickly in sunny, exposed places, in hot, dry and windy conditions, and if the soil surface is bare and rough. A "thirsty air" will quickly dry out the soil surface.

When the crop is young, the soil surface is often bare. The soil warms up in the sun, and water evaporates quickly, leaving the young plants without moisture. That can ruin an entire crop.

For seeds to germinate and grow well, the soil temperature around their roots should be 25–35°C. Bare soil can get a lot hotter than this. You can use a thermometer to show how hot it can get.

You can reduce the amount of water lost through evaporation in various ways:

- Keep the soil surface covered with mulch. The mulch may be natural (like cover crops or crop residues) or artificial (like plastic sheets).
- Protect the soil from being dried out by strong winds (e.g., by planting windbreaks, alley crops or intercrops)

Measuring evaporation

► *Exercise 10.2 Evaporation.*

► *Exercise 10.6 Mulching to reduce evaporation.*

Transpiration

How do plants get water and nutrients? Through their roots. They absorb the nutrients, then breathe out some of the water through tiny holes on the underside of their leaves. This is called **transpiration**.

The drier and hotter the air, and the stronger the wind, the more water plants lose in this way.

If the plants can get enough water from the soil, the tiny holes stay open. But if there is not enough, they close the holes, so they lose less water. That is how plants protect themselves against drought.

But plants cannot grow properly without water. They wilt and may die. The more water that they take up, the faster they grow (unless the soil is too wet – as the roots need air as well as water).

The amount of water a plant needs depends on its stage of growth. Before it germinates, it does not transpire. As it adds more and more leaves, it transpires more, so needs more water. If the ground dries up for a short time, the plant stops transpiring, but starts again as long as its leaves and roots are healthy. When the plant reaches the end of its life cycle, its leaves and roots dry up and stop transpiring, and the plant dies.

Weeds transpire too. They also take water from the soil and use it to grow. So a lot of weeds would steal precious water that your crops could use. That is one of the reasons it is important to control weeds.

You can learn how to recognize weeds which steal water from your crops by looking at their rooting systems.

► *Exercise 6.8 Becoming a root doctor.*

Cover crops and intercrops also use water. In semi-arid areas, they may compete with crops for water. The farmer must decide: is it better to plant cover crops to protect and enrich the soil, even though they may use precious water? Or is it better to leave the soil between the crop rows bare – and so letting some of the water run off? Is it possible to leave enough mulch on the soil to stop the water from running off? Unfortunately there are no easy answers to these questions. Farmers should test the options and choose what works best in their own conditions.

Measuring transpiration

► *Exercise 10.3* for how to measure transpiration in the field.

Surface runoff

If rainwater does not soak into the ground, it gathers on level surfaces or runs off downhill, carrying soil particles with it. It eventually reaches the nearest river. The flow of water may be strong enough to erode forming rills and gullies that destroy cropland and damage roads and buildings.

More water soaked up by the soil means less runoff. The less water that sinks into the soil, the more that runs off over the ground. The soil's ability to soak up water (► *Table 10.2*) determines the amount of runoff. There is more runoff (so erosion is more likely) during heavy storms and on steep slopes, on soils that have a surface crust or dense, compact layers, and if the ground is already wet.

You might plan to collect water in one place and channel it to your fields. This is called **water harvesting**. If you do this, make sure that the area where you collect the water soaks up as little as possible. The best areas for this are bare rock, shallow soils with impermeable rock underneath, or clay soils. ► *Module 11 Harvesting water for crops* and *Module 12 Harvesting water for people and livestock* for more.

Infiltration and permeability

When rain hits the ground, some of it soaks into the soil. This is called **infiltration**.

If it rains only a little, all the water will probably soak into the ground. But if it rains heavily, only some will soak in, and the rest will run off downhill and cause erosion and flooding downstream. The more water that soaks in, the less is wasted as runoff and the more there is for crops and for living organisms in the soil.

If water sinks into the soil only slowly, the top layers may be dripping wet, like a wet sponge, while the layer below may still be dry. This depends on the soil's **permeability**. Very permeable soils (like sands) let water pass through easily, so dry out quickly. Impermeable soils (like heavy clays) do not let water pass through, and can get easily waterlogged. If the soil is waterlogged, many plants cannot grow well because their roots need air as well as water.

The size of the soil particles, and the size of the pore spaces between them, affect what happens to the water. The smaller the particles, and the smaller the pores, the more tightly the soil holds onto water.

- Big pores (bigger than 0.05 mm across, or 1/20th the width of a human hair) let water drain through. **Sandy soils** have big pores.

- Medium-sized pores let water in fairly quickly. They also hold onto water, but not very tightly, so crop roots can still pull it out and use it. **Loams** have medium-sized pores.
- The tiniest pores let water in slowly, and hold onto it very tightly, so crop roots cannot get at it. **Clays** have tiny pores.

The best soils are loams, where water sinks in quickly, but does not pass through too fast. Loams let some of the water drain away into the groundwater (that is good for wells, springs and rivers). But they hold onto the rest of the water so crops can use it (► *Table 10.2*).

► *Exercise 10.5 How the soil holds water.*

The soil also acts as a filter. It cleans the water that passes through it. That is why water in springs and wells is usually clear: it has been cleaned by the soil. If the soil is too permeable, it does not clean the water properly, and the water can contain harmful chemicals and disease organisms.

Table 10.2. How much water can different types of soil soak up?

This type of soil…	…can soak up this many millimetres of water in an hour
Sand	more than 30
Sandy loam	20–30
Loam	10–20
Clay loam	5–10
Clay	1–5

Source: Anschütz et al. (2003)

Measuring infiltration

► *Exercise 4.5 Measuring how fast water sinks into the soil.*

► *Exercise 10.4 Percolation.*

How do you know if your crop is short of water?

Plants take up water through their roots, and then lose it through tiny holes in their leaves. If there is not enough water in the soil, the holes in the leaves close up, and the plant loses less water. But it will also grow more slowly, or stop growing completely.

It is easy to see if a crop is short of water today:

- The leaves and stems wilt
- The leaves roll up
- The leaves are hot to touch
- The leaves have little water in them.

How about if water was short last week, or the week before? Look for the following signs:

- Poor germination (fewer seeds than expected sprouted, so the crop stand is patchy and uneven)
- The plants are short and stunted
- The leaves look older than normal
- The grains are not filled
- The plants produce few flowers or fruits.

► *Exercise 10.7 The ability of soils to hold water.*

Why manage rainwater?

Because crops often go thirsty. There may be enough water overall, but rain falls at the wrong time and in short, intense storms. The rest of the time is dry. That means lower yields, or no yield at all.

Above we learned what happens to rainwater in the field. Let us have another look.

Water can come into the field in three ways:

- Through rain (or snow, dew, hail, and so on)
- By natural runoff from uphill
- Through irrigation.

Several things can happen to this water:

It can sink through the soil and be held there

- It can sink all the way through the soil, down into the groundwater
- It can run off the surface and out of the field
- It can evaporate from the soil or from puddles
- It can be taken up by plant roots and transpired into the air.

We can write the same thing as an equation:

Water stored		Water coming in		Water going out (unproductive losses)		(productive losses)
*Water stored in the **S**oil*	=	***R**ainfall + Runoff from **U**p-hill + **I**rrigation*	–	***P**ercolation + Runoff **D**ownhill + **E**vaporation + Transpiration by **W**eeds*	+	*Water used by the **C**rop*
S	=	*R + U + I*	–	*P + D + E + W*	+	C

Figure 10.7. Calculating the amount of water stored in the soil

► *Exercise 11.2 Water balance in a field.*

For the crop to grow well, there has to be enough water stored in the soil to meet the crop's needs. We can increase the amount of water stored in the soil (S) in two ways:

- **By increasing the amount of water coming in** – for example, by diverting runoff from uphill (U) into our fields, or by irrigating (I). We cover this in ► *Module 11 Harvesting water for crops*.
- **By reducing the amount of water going out** (unproductive losses) – by making the soil hold more water (E), and by reducing percolation (P), runoff downhill (D), evaporation (E) and transpiration by weeds (W).

The rest of this module helps you work out how much water your crops need and calculate how much water your soil can hold. It also shows how to help soil retain water and assist crops access it.

► *Exercise 10.1 The water cycle.*

► *Exercise 11.2 Water balance in a field.*

Water for crops

How much water does a crop need? That depends on various things:

- The weather
- The type of crop
- The length of the growing season
- The growth stage of the crop

We will look at each of these in turn.

The weather

Crops growing in hot, sunny places, and on hot days, need more water than those growing where it is cool and cloudy. Windy weather means crops need more water than if the air is still.

► *Table 10.3* uses grass as an example. It shows how much water a mature crop of grass needs in different places. It needs 2–3 millimetres of water a day in the cool humid tropics (as in the cool highlands of East Africa), but 6–8 millimetres a day in warm, arid areas (in the dry lowlands).

The type of crop

Some crops are "thirsty" – they need a lot of water to grow well. Other crops grow well even though water is short. ► *Table 10.4* shows which crops need only a little water, and which need a lot. Note that grass is a "normal" crop, along with cacao, carrots, coffee and so on.

Table 10.3. How much water does a mature grass crop need every day in the tropics and subtropics?

	Mean daily temperature (°C)		
	Cool (10°C)	Moderate (20°C)	Warm (over 30°C)
Humid and sub-humid areas	2–3 mm	3–5 mm	5–7 mm
Arid and semi-arid areas	2–4 mm	4–6 mm	6–8 mm

Many common crops need more water than grass. They include beans, maize and potatoes, which all need about 10% more water than grass. Some crops (like banana and sugarcane) need 20% more water. A few crops (like citrus and cucumbers) need less water than grass.

The length of the growing season

Some crops, such as peas, grow fast and can be harvested quickly. Because they are in the field for only a short time, they generally need relatively little water.

Others, such as melons, grow more slowly, and take a longer time to mature. They need more water.

The growth stage of the crop

A fully grown crop will need more water than a crop that has just been planted. Most crops have four distinct stages of growth:

- **Initial stage.** This lasts from sowing or transplanting until the crop covers about 10% of the ground. During this time, the crop needs perhaps 50% of the water it needs when it is fully developed.
- **Crop development.** This starts at the end of the initial stage, and lasts until the crop covers 70–80 % of the ground. The water need rises from 50% gradually up to 100% of the daily need.
- **Mid-season.** This period lasts until maturity; it includes flowering and grain-setting. The crop needs the most water (100%) at this time.

Table 10.4. Crops that need a little water, a normal amount, and a lot

Need little water	←	Normal amount of water	→	Need a lot of water
These crops need **30% less** water than grass	These crops need **10% less** water than grass	These crops need about the **same** amount of water as grass (▶ *Table 10.3*)	These crops need **10% more** water than grass	These crops need **20% more** water than grass
Citrus Olives Grapes	Cucumber Radishes Squash	**Grass** Cacao Carrots Coffee Crucifers (cabbage, cauliflower, broccoli, etc.) Lettuce Melons Nuts and fruit trees (e.g. apples) grown without a cover crop Onions Peanuts Pepper Spinach Tea	Barley Beans Cotton Eggplant Flax Lentils **Maize** Millet Oats Peas Potatoes Safflower Small grains Sorghum Soybean Sugar beet Sunflower Tobacco Tomato Wheat	Banana Paddy rice Sugarcane Nuts and fruit trees with cover crop

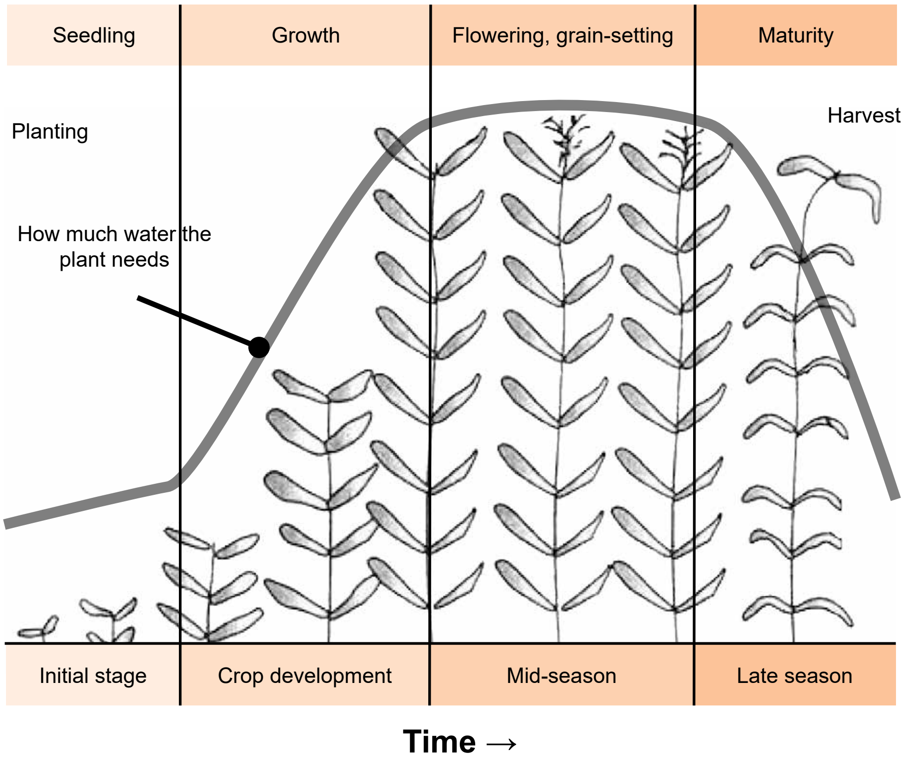

Figure 10.8. How much water a crop needs during its life

Adapted from: Allen et al. (1998)

Late season. This is when the crop is ripening; it lasts until harvest. The amount of water needed drops from 100% down to 25%, when the plants dry out. Some crops are harvested green, so the amount of water needed remains 100% until harvest.

Averaging these water needs out, most crops need about three-quarters (0.75) of their mid-season water requirement over the whole growing season.

Calculating how much water a crop needs

You may be able to get estimates of how much water various crops need from your local research station, extension service or Ministry of Agriculture.

If you cannot get these figures, you can calculate how much water a crop needs like this:

Check ► *Table 10.3* and decide what area you live in. Note down how much water a grass crop needs in your area.

Check ► *Table 10.4*, and note how much water your particular crop needs compared to grass.

Work out how long the growing season is for your crop.

Calculate the following:

Amount of water needed (mm)	=	Average daily water need (from step 2 above)	x	Number of days in growing season	x	0.75

In semi-arid areas, the amount of water provided by the rainfall over the growing season may not be sufficient to cover the amount of water needed by your crops. Your crops will require extra water to survive.

Extra water required = amount of rainfall – amount of water needed by your crops.

In this case, you should consider harvesting water to make up the shortfall (► *Module 11 Harvesting water for crops*). You can also consider growing a "less thirsty" crop.

Example

You live in a warm, semi-arid area with about 500 mm of rain in the growing season. Your are interested in growing maize. You can see from ► *Table 10.3* that grass in your area needs 6–8 mm of water a day.

Checking ► *Table 10.4*, you find that maize needs about 10% more water than grass. So your maize will need something like 6.6 to 8.8 mm of water a day. Take the average (7.7 mm per day) as an estimate.

You know that your maize variety takes 140 days from planting until it is ready to harvest.

Your maize crop will need this much water:

7.7 mm x 140 days x 0.75	=	808.5 mm of water

That is about 300 mm more rain than your area typically receives in a season (500 mm). You can expect your crop to go short of water.

808.5 mm – 500 mm rain	=	about 300 mm more water needed

The soil's ability to hold water

Water-holding capacity

After several days of continuous rain, a soil may be wet through and through. It is full of water, from top to bottom, and cannot hold any more. It is like a sponge that is dripping wet. This soil is said to be **saturated**.

If it stops raining, the extra water gradually drains away over a day or so. The soil is still wet, but no longer full. It is like a wet sponge where the water has drained out – still full of water, but no longer dripping. This soil is at **field capacity**.

If it does not rain again, the soil will dry out some more. Some water will evaporate from the surface, and crops and other plants will take up water through their roots. Eventually they will not be able to get any more water out of the soil, and they will begin to wilt. The soil is like a sponge that has been squeezed hard to get as much water as possible out. This soil is said to be at **wilting point**. If there is no more rain, the plants will dry out and die.

How much water can plants use? The extra water in the soil when it is saturated is there only for a short time, so plants have little chance to use of it. Realistically, they can use only the water between the stage of field capacity and the wilting point. This is called the **maximum available water**.

A soil at wilting point still contains some water. But it holds onto the water so tightly that plants cannot use it. It is like a sponge that has been squeezed out: you can still feel it is damp, but you cannot press any more water out.

Different soils can hold different amounts of water.

- A **sandy soil** absorbs water quickly (► *Table 10.2*) but can hold onto very little of it, because its pores are too big.
- A **clay** absorbs water only slowly because its pores are very small. But it holds onto a lot of water, and holds some of it very tightly.
- A **clay loam** holds a little less water than a pure clay, but holds onto it less tightly, so more is available for the crops.

► *Table 10.5* shows how much water (in millimetres) each centimetre of soil can hold when it is at field capacity, and when the soil is so dry that plants begin to wilt. The difference between these amounts (the last row in the table) is the amount of water the soil can contain that plants can use.

► *Exercise 10.7 The ability of soils to hold water.*

► *Exercise 10.5 How the soil holds water.*

Table 10.5. How much water can different types of soil hold?

	Sand	Sandy loam	Loam	Clay loam	Clay
	mm per cm depth of soil				
Field capacity (wet soil, a few days after rain)	0.8	2.0	2.7	3.2	4.0
Wilting point (dry soil)	0.3	0.8	1.2	1.4	2.5
Available water (the amount plants can use)	0.5	1.2	1.5	1.8	1.5

These figures are averages. They may vary depending on the soil structure and organic matter.

Rooting depth

The other thing you must consider is the rooting depth. Plants can use only the water that they can reach with their roots. Deep-rooted plants can get more water than shallow-rooted ones. That is why deep-rooted plants (such as trees) stay green for longer than shallow-rooted ones (such as some grasses).

If the soil is shallow or if there is a hardpan, the rooting depth will be less.

► *Exercise 6.8 Becoming a root doctor.*

► *Exercise 8.4 Looking at roots.*

Calculating the maximum amount of water available to your crop

1. Decide what type of soil you have: sand, loam, clay, etc.
2. Determine the rooting depth (in centimetres) of the crop you are interested in.
3. Multiply the rooting depth by the relevant number from the last row of ► *Table 10.5*. This is the amount of water that the soil can make available to your crop.

Maximum available water (mm)	=	Available water (mm/cm)	x	Rooting depth

How can you use the answer?

- If you know how much water your crop needs every day (► *Table 10.4*), you can tell how long your crop will be able to grow before it starts running out of water.
- You know how much water you can add to the soil without overfilling it. There is no point in harvesting more water and diverting it onto your fields if the soil cannot hold it. For example, if your soil can hold only 200 mm of water, but you divert 300 mm of water onto it, 100 mm of water will sit on the surface in puddles (waterlogging the soil), or will run off or drain down through the soil, taking valuable nutrients with it.

Example 1

You have a deep clay loam, and you find your maize plants have roots down to about 90 cm.

Total available water (mm)	=	1.8 mm/cm x 90 cm
	=	162 mm

Your soil can hold a maximum of 162 mm of water at any one time that your maize plants can use. Note that maize needs more water than this to grow well (► *Table 10.4*). But there should be enough water in the soil to let the maize plants continue to grow for several weeks without rain.

Example 2

You have a deep clay loam, but it has a hardpan at 25 cm depth. Very few roots manage to grow down through this hardpan.

Total available water (mm)	=	1.8 mm/cm x 25 cm
	=	45 mm

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Box 10.2. Things that affect the soil's ability to hold water

- Soil texture.
- Organic matter and soil life.
- Soil structure.
- Soil depth.
- Compacted soils, hardpans and surface crusts.
- Slope and soil surface.
- Soil moisture before the rain.
- Vegetation cover.
- Soil health.
- Tillage.

Your soil can hold only 45 mm of water. Your maize plants will quickly run out of water. You should try to break up the hardpan somehow to allow the roots to grow down deep in a soil which is enabled to hold more water.

► *Exercise 11.2 Water balance in a field.*

Helping the soil retain water

If you can make more water sink into the soil, more will be available for your crops, there will be more water in wells and springs, and there will be less erosion and flooding.

What affects how much water soaks into the soil, and how much the soil can hold? And what reduces the amount of water that is lost through evaporation, transpiration and percolation? This depends on many factors (► *Box 10.2*).

Below are some ways you can influence each of these factors.

Soil texture

Most water finds its way into the soil through tiny spaces or pores between particles of soil. Water soaks in more easily if these spaces are big (as in sandy soil) than if they are small (as in clayey soil). That is why sandy soils are said to be "thirsty".

Sandy soils absorb water more quickly than clays and loamy soils, but they cannot hold onto it. Their large pore spaces let water through easily, and they dry out quickly. That makes sandy soils more prone to drought. ► *Module 4 Knowing your soil* for more.

What to do

- Add organic matter to the soil.
- Otherwise, there is not much you can do about the soil texture. ► *Module 4 Knowing your soil*

Organic matter and soil life

A soil rich in organic matter can absorb and hold a lot of water. Adding organic matter can help sandy soils hold onto more moisture. Earthworms, termites, beetles and millipedes make channels and burrows that allow water to soak into the soil.

What to do

- Add mulch to protect the soil surface.
- Add organic matter (manure, compost, green manure) to feed soil life and improve the soil structure.
- Add organic matter to feed soil life.
- Avoid disturbing the soil.

► *Module 5 Using organic materials*, *Module 6 Encouraging soil life* and *Module 8 Conservation agriculture*.

Soil structure

Water finds its way into the soil through cracks and pore spaces. A soil that has a good, crumbly structure, that breaks easily into separate clumps, will have more cracks and will absorb water more quickly, and will hold onto more water, than one that is massive and compacted. Ploughing or hoeing, or trampling by animals – can damage the soil structure by creating a crust or hardpan that will prevent water from soaking in.

What to do

- Apply conservation agriculture (particularly minimum soil disturbance)
- Add organic matter.

► *Module 4 Knowing your soil* and *Module 8 Conservation agriculture*.

Compacted soils and hardpans

A soil that is compacted or has a hardpan will not be able to absorb much water. It may waterlog easily and then dry out quickly. Roots will not grow well; they may grow sideways instead of downwards into the soil.

What to do

- Plant crops that have deep, strong roots to break the hardpan.
- Use a subsoiler or ripper if you can use a tractor or oxen to pull them. If you do not have this equipment, perhaps you can group together with other farmers to buy it. ► *Module 8 Conservation agriculture.*
- Till a deep layer of soil to let roots grow down, and use other organic farming techniques. This "double-digging" is a lot of work, but you should not need to do it again for many years.

Surface crusting and sealing

Heavy raindrops break up the clumps on the surface, and fine particles can clog up the holes in the surface. That stops water from soaking in. Clayey or loam soils can form these crusts easily.

What to do

- Keep the soil covered (e.g., with mulch) to protect the surface from heavy rain.

Soil depth

Deep soils can hold more water than shallow soils – because they have more room for the water. A shallow soil gets full of water quickly.

A deep soil with a good structure will be able to soak up water for a long time, even during a long, heavy downpour. But a deep soil may have a hardpan, perhaps caused by ploughing. Water finds it hard to soak in through this hard layer, and few roots can grow through it. In effect, a hardpan turns a deep soil into a shallow one. ► *Module 4 Knowing your soil* for more.

What to do

- If you have plenty of land, select the areas where the soil is deep

- If you do not have plenty of land, bring in soil from elsewhere and add lots of organic matter to build up the soil.

Slope and soil surface

Water runs off faster on steep slopes, because it has less time to soak into the ground. Even on gentle slopes, heavy rains can produce strong flows of water that may wash a layer of soil off the whole land surface, or concentrate and erode rills and gullies.

If the surface is smooth, water will flow away easily. Making the surface rougher (for example with mulch, ridges and bunds) will keep water on the land. Try to hold as much water on the land as possible so it has time to soak into the soil.

What to do

- Cultivate along the contour (not up and down the slope) to slow down the flow of water and to prevent it from forming strong flows. It will also trap soil that is washed down from uphill. Contour farming includes ploughing, making furrows and planting along the contour lines of a hillside. Rain falling on the ground will not be able to flow far. It will sink into the soil where your crop roots can find it.
- Use tied ridges to hold water. Tied ridging involves making small bunds or ties every metre or so across furrows. Water spreads better in the furrows and seeps into the soil more uniformly
- Make earth bunds or stone lines, and terrace land on steep slopes along the contours.

► *Exercise 10.8 Soil cover to reduce erosion.*

► *Module 11 Harvesting water for crops.*

Soil moisture before the rain

If the soil is already very wet, it cannot hold much more water.

What to do

There is not much you can do to make soil that is already wet absorb more water.

Vegetation cover

A dense cover of plants protects the soil from heavy rain, and stops the surface from sealing. Roots and organic matter in the soil increase the number of pores, allowing more water to infiltrate. Plants also slow down the flow of water on the surface, giving it more time to soak in. Roots form holes and channels where water can find its way into the ground.

What to do

- Plant crops at the optimum plant spacing so they cover the soil when they grow.
- Plant intercrops, relay and cover crops to reduce the amount of bare soil and extend the time when the ground is covered.

Weeds

Weeds protect the soil, but they also steal water from your crop. No only that: they also compete with the crop for light and nutrients. It is worth the extra time and money to control them: fewer weeds means bigger yields.

What to do

- Weed the field several times during the growing season.
- Prevent weeds from growing by planting cover crops or intercrops, or by spreading mulch.
- Cut weeds before they flower to prevent them from producing seed. Leave the dead weeds in the field as mulch. ► *Module 13 Managing weeds*.

Tillage

Too much tillage breaks down the soil structure, creating a compacted or powdery soil that can absorb little water. Repeated ploughing or hoeing can create a hardpan that stops water from sinking in.

What to do

- Practise minimum tillage.
- Avoid ploughing. ► *Module 8 Conservation agriculture.*

Helping the crops access water stored in the soil

Here are some ways to help the crops access available water.

Plant density

Fewer plants need less water. But be careful: fewer plants may also mean less yield. And if the crop does not cover the ground, you may have more weeds, which compete with the crop for moisture. You may also get more erosion. So it may be better to plant at a close spacing in order to avoid these problems.

What to do

- Plant at a density that allows the crop to use up all the moisture available, but does not need more moisture than the soil contains.

Drought-resistant crops

Some crop varieties mature early, so avoid drought that occurs late in the season. Other varieties are naturally drought-resistant: they grow well even if there is little water. You may also be able to switch to another type of crop that needs less water.

What to do

- Choose an early-maturing variety of your crop.
- Choose a drought-resistant variety of your crop.

- Switch to another crop that needs less water. For example you could switch from maize to sorghum.

Planting time

If you plant early, you can take advantage of the first rains, and avoid drought later on if the rainy season turns out to be short. If you practise conservation agriculture, you can plant earlier than farmers who have to wait until they have ploughed their fields.

What to do

- Plant as soon as the rainy season starts.

Listen to the weather forecast

Weather forecasters can predict the onset of the rains and recommend to farmers when to plant.

What to do

- Listen to the radio to find out when the rains are due. Plan what crops to plant, and when to plant them, accordingly.
- Local people are also good at predicting the weather. Use local traditions that have proven useful as a guide to what and when to plant.

Control weeds

Weeds steal water from your crop. It is worth to spend time and money to control them: fewer weeds mean bigger yields.

What to do

- Weed the field several times during the growing season.

Make your own decisions

Many of these recommendations also have disadvantages:

- Switching to another variety or crop may mean giving up an important staple food, or reducing your income if the price is lower.
- Planting at a lower density means less plants and perhaps more weeds.
- Planting early is risky if the early rains fail. And sowing late may mean you get good prices if you harvest out of season.
- Controlling weeds is difficult if you are away working somewhere else.

Discuss the advantages and disadvantages of these recommendations with the farmer field school members. They have to make their own decisions about what to do. They can learn from what other farmers have done, and may be able to test ideas out on a small scale before deciding to adopt them.

Exercise 10.1 The water cycle

This exercise helps farmers understand how water circulates in the village and around their crops in their fields.

Steps

1. Ask the participants to brainstorm where water comes from and where it goes. They should list the various components (sun, clouds, vegetation, lakes, rivers, sea, soil) and processes (rainfall, evaporation, transpiration, percolation, etc.) of the water cycle.

Village level

2. Divide the participants into small groups of 3–5 people.
3. Ask each group to draw a village transect diagram (► *Exercise 2.2 Transect walk*). Ask them to show on it where water is found (e.g., in rivers, streams, wells, the soil, etc.).
4. Ask each group to discuss how water circulates using the transect diagram (e.g., what happens to water when it rains?). The group should draw arrows on the diagram to show where water comes from (rain, dew, etc.) and where it goes (infiltration, evaporation, transpiration, runoff, etc.). Ask them also to show where water is stored (in the soil, as groundwater, in lakes and rivers, in the sea and as clouds ► *Figure 10.3*).
5. Ask the groups to discuss how important the different types of water are (i.e., rainwater, surface water, groundwater).
6. Ask the groups to compare the situation in the dry season and the rainy season (it may be helpful to refer to the seasonal calendar, ► *Exercise 2.3*). Ask when water is available, and what are the main differences between the dry season and the rainy season?
7. Invite each group to present its results to the plenary. Discuss the differences between the groups.

Crop level

8. Ask each group to draw a crop plant and its roots (like ► *Figure 10.4*).
9. Ask the groups to discuss how rainwater goes out from the field:

- What are the "productive" losses (water used for crop growth) and "unproductive" losses?
- How has rainfall, evaporation, runoff and deep percolation changed over the years? Use the symbols =, ↑ or ↓ to show changes.
- How can farmers stop or reverse negative trends?

10. Ask the groups to identify practices (such as mulching) that reduce the "unproductive" losses and increase the amount of water in the soil.
11. Invite each group to present its results to the plenary. Discuss the differences between the groups.

Learning objective

Understand how water circulates in the local area.

Timing

At any time of the year. Best when the group starts learning about water management.

Preparation

–

Duration

2 hours.

Materials

Large pieces of paper, marker pens.

Exercise 10.2 Evaporation

Learning objective

Measure the amount of water that evaporates under different conditions.

Timing

On a sunny day, at any time of the year.

Preparation

–

Duration

30 minutes to set up the experiment. Check again about the same time the next day.

Materials

Several flat pans or trays that can hold water, ruler, water.

This exercise enables farmers to measure the amount of water that evaporates from the soil or from lakes and ponds.

Steps

1. Fill several shallow pans with the same depth of water. Measure the depth of the water (in millimetres) in the pans.
2. Put one pan in the direct sun and another in the shade (for example, under a tree). Put some cut grass or dry maize stalks over the third pan and leave it in the sun. If you have more pans, you can put them in different locations – for example, in a windy place, inside a house, or on the ground beneath a crop of maize. Put the pans where children and animals will not interfere with them.
3. Leave the pans overnight.
4. At the same time on the next day, measure the depth of the water in each of the pans.
5. Discuss with the participants what they have observed.

Questions to stimulate discussion

- In which pan did the most water disappear? In which did the least disappear? Why?
- What happened to the water that evaporated? Is it lost forever?
- Would more or less water evaporate on a cloudy day? If the weather is cool? At a different time of year?

Exercise 10.3 Transpiration

This exercise helps farmers see that plants lose water through their leaves, and that plants exposed to the sun lose more water than those in the shade.

Steps

1. Select a field with tall, leafy plants, where the soil is moist.
2. Select a tall plant or clump of plants in the shade. Tie a plastic bag over the upper stems to enclose many of the leaves as possible.
3. Wait 10–15 minutes, then remove the bag. Observe the water droplets that have formed inside.
4. Repeat steps 1–3 for plants in the sun, or at different hours of the day (early morning, late afternoon, evening).
5. Compare the differences.

Learning objective

Visualize the transpiration process by observing water transpired from the leaves.

Timing

At any time of the year when the soil is moist and plants are growing. Best when the group starts learning about water management.

Preparation

–

Duration

30 minutes per demonstration.

Materials

Dry, clean, transparent plastic bag, about 30 cm x 40 cm; string.

Adapted from

SAFR (2004)

Figure 10.9. Checking the transpiration of a crop

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Exercise 10.4 Percolation

Learning objective

Understand how water percolates through the soil and how it may recharge the groundwater.

Timing

At any time of year.

Preparation

Collect three different types of soil: a sandy soil, one rich in organic matter, and a clayey soil.

Duration

Initially 1 hour; more observations the next day(s).

Materials

Three 2-litre plastic bottles per group, sharp knives, buckets of water, cups.

Adapted from

FAO (2000)

This exercise shows that water moves downwards at different speeds through different types of soil. It helps farmers appreciate the differences between different soil types, and shows how it may recharge the groundwater.

Steps

1. Divide the participants into small groups of 3–5 people. Each group does the exercise separately.
2. Cut the bottles in half horizontally. Turn the top halves over so the necks are down, and put a stone in the necks to partly block them.
3. Fill each of the three top halves with a different type of soil. Press the soil down so that water will not leak down the inside of the bottle, but not too hard!
4. Put the soil-filled top halves neck-down into the bottom halves of the bottles, like a cup and saucer.
5. Pour a cupful of water into each top half. Let the water drain through the bottle neck so it collects in the bottom half of the bottle underneath. If you have a watch, count how long it takes for water to start dripping out of each of the bottle necks.
6. Wait until water stops dripping out, then measure how much water collects in each of the bottom halves. Work out how much is left in each of the soils.
7. Each group presents their results for each type of soil.
8. Discuss the findings in the plenary.

Questions to stimulate discussion

- How much water passed through each of the soils? How quickly? How much did not pass through? What happened to it? What holds it in the soil?
- Which soil type holds the most water? Which holds the least? Which soil would support crops longest during a dry spell?
- What factors affect how quickly water passes through the soil?
- Where does the water go when it reaches the bottom of the soil?
- How deep is the groundwater in your area? How does it go up and down?
- Compare the situation in the village over the years. Is there more or less groundwater now? How about the groundwater quality? How has the situation changed over the last 10 or 20 years?
- What are the main causes of groundwater pollution?

Exercise 10.5 How the soil holds water

This exercise uses a sponge to demonstrate how water holds onto water. It illustrates three levels of moisture in the soil: saturated (when the sponge is completely full of water and dripping wet), field capacity (when the sponge has stopped dripping but is still wet), and wilting point (when the sponge has been squeezed).

Steps

1. Show the participants the sponges. If the participants are not familiar with sponges, explain what they are and what they are used for.
2. Dip one of the sponges in the water, and take it out without squeezing it.
3. Stand the wet sponge up in an empty bowl, and allow the water to drip out. Note how it dries out from top to bottom. Note how much water comes out and how long it takes to stop dripping.
4. When the sponge has stopped dripping, squeeze it out as well as you can. Note how much water comes out.
5. Point out that the sponge is still wet, although no water comes out anymore. Pass the sponges around the participants so they can feel the difference between the wet sponge and the dry sponge.
6. Repeat the exercise and explain how soil water is held in the soil.
7. If you have a set of scales, you can weigh the sponge when it is dry, when it is full of water, after it has stopped dripping, and after you have squeezed it out. That will tell you how much water the sponge holds at each time.

Questions to stimulate discussion

- Where does the water which "drips" from the soil go?
- In a soil, what "squeezes" the water out of the soil?
- Where is the water which you can feel, but not squeeze out of the sponge?
- What would happen to plants when the soil has the same amount of water as the sponge after you have squeezed it out?
- How can you overcome this problem?
- What would happen if we put the wet sponge in the sun? What if we cover it with a blanket?

Learning objectives

Understand what happens to water in the soil.

Understand the water-holding capacity of soils.

Understand the importance of soil water.

Understand soil water storage and how plant roots can access soil water.

Timing

When discussing the water-holding capacity of soils.

Preparation

Leave the sponges to dry in the sun.

Duration

30 minutes.

Materials

Two sponges, bucket of water, bowl, weighing scales (if possible).

Exercise 10.6 Mulching to reduce evaporation

The exercise demonstrates how water evaporates from the soil, and how mulching can reduce the amount of water that is lost.

Learning objectives

Observe evaporation from the soil.

Understand the effect of clearing and ploughing on the water in the soil.

Understand the importance of soil water.

Understand the role of soil cover on conserving soil water.

Timing

On a sunny day, when discussing soil moisture or soil cover.

Preparation

Identify a soil with a good organic matter content, or alternatively use compost.

Duration

30 minutes to set up the experiment.

Leave for a few hours, then 30 minutes for observation and discussion.

Materials

3 bowls, soil, water, cup, dry grass clippings, marker pen.

Adapted from

FAO (2000), FARMESA (2003) and FAO (2002)

Steps

1. Fill two of the three bowls with soil.
2. Pour equal amounts of water into all three bowls.
3. Put the dry grass clippings on top of the soil in one of the bowls.
4. Mark the water level in the bowl that contains only water.
5. Place the three bowls together in the sun and leave them for a few hours.
6. Observe what happened to the bowls.

Questions to stimulate discussion

- Did water disappear from the bowl that contained only water? What does the soil look like in the two other bowls? Does the soil feel moist?
- What does this mean for seeds that germinate in the soil?
- What would happen to water in the soil if the soil is tilled several times?
- If there is a dry spell during the growing season, in which soil would plants survive longer?
- What problems would you face if you want to use mulch on your fields?
- Apart from mulch, what other uses are there for crop residues?

Exercise 10.7 The ability of soils to hold water

This exercise helps farmers appreciate the amount of water that different soils can hold.

Steps

1. Place the funnel in the measuring jar.
2. Place the filter paper or piece of cloth in the funnel.
3. Put a cupful of soil in the funnel.
4. Pour a certain amount of water into the funnel (e.g., 20 ml). Collect the water that drips through the funnel in the measuring jar. It may take 10–15 minutes for the water to stop dripping from the soil.
5. Wait until the water has stopped dripping out of the funnel, then read of the amount of water in the measuring jar (or weigh it with the scales).
6. Record the results in ► *Table 10.6*.
7. Throw soil and filter paper or cloth in the bin and repeat steps 1–6 for the other soils.
8. Discuss the results with the whole group.

Questions to stimulate discussion

- Which soil type holds the most water?
- Which soil type holds the least water?
- Which soil type would support plant growth longest during a dry spell?

Table 10.6. Form for recording how much water the soil can hold

Soil type	Amount of water added to the soil (ml)	Amount of water collected in the jar (ml)	Amount of water still in the soil (ml)
	W	J	W – J
Clay			
Loam			
Sand			
Compost			
…			

Learning objectives

Investigate the amount of water different soils can hold.

Understand how water moves through the soil and is held by soil particles.

Understand the role of organic matter in holding water.

Timing

After ► *Exercise 5.1 Observing soil organic matter.*

Preparation

Collect various types of soil: sandy, clayey, loamy; poor and rich soils according to farmers, and compost.

Duration

1 hour, but it may take some time before the water stops dripping from the soil samples.

Materials

Samples of different types of soil and compost, filter papers or pieces of cloth, funnels made from plastic soft-drink bottles, measuring jar or scales, jars or cups.

Exercise 10.8 Soil cover to reduce erosion

Learning objectives

Visualize the impact of intense rainfall on surface runoff.

Visualize the beneficial influence of mulch, contour bunds and tied ridges.

Timing

Prior to the rainy season in order to ensure that measures can be taken prior to heavy rains.

Preparation

Make wooden boxes.

Collect enough soil to fill the boxes, and leave it to dry in the air.

Duration

1 hour.

Materials

Two wooden boxes, 30 cm wide, 40 cm long and 10 cm high. Make one end 2 cm lower than the other so water can flow out.

Two large bowls, enough dry soil to fill the two boxes to a depth of 8 cm, watering can with a coarse sprinkler head, chopped crop residues to cover one of the boxes.

Adapted from

FAO (2000)

This exercise demonstrates the effect of mulch or other forms of soil cover to reduce runoff and erosion, and to increase infiltration. It also shows how contour bunds and tied ridges can slow down runoff and keep water on the land.

Steps

1. Remove stones and roots from the soil, and fill the boxes to 8 cm depth, so that the soil at the lower end is level with the outlet.
2. Add a layer of chopped crop residue about 0.5 cm thick as mulch on top of the soil in one box.
3. Put the boxes at an angle of about 25%, with the outlets downhill (to simulate a slope). Place the bowls beneath the outlet to catch water.
4. Simulate a heavy rainstorm by holding the watering can about 2 m above each box. Water the soil as uniformly as possible.
5. Record how much water is collected in each bowl, and note its colour.
6. As soon as the water stops running off, dig out the soil at the downhill end of the boxes. Note how deep the water has penetrated.
7. Make contour bunds and tied ridges with your finger in the soil without the mulch. Repeat steps 3 to 5.

Questions to stimulate discussion

- What changes have happened to the soil surface, and to the holes and gaps in the surface?
- In which box did most water soak in? Why?
- How much water is stored in the soil?
- How do crops benefit from soil cover and contour bunds?
- What evidence can you see of erosion?
- What problems would you face if you want to use mulch on your fields?
- Apart from mulch, what other uses are there for crop residues?

Module 11. Harvesting water for crops

This module focuses on how to harvest water so you can use it to grow crops. That is why it is called "water harvesting".

The next module, ► *Module 12 Harvesting water for people and livestock*, focuses on how to harvest water and store it in ponds or tanks so people and livestock can use it.

Learning objectives

After studying this module, you should be able to:

Plan how to harvest water for crops.

Work out how big a catchment area you need to supply your crops with enough water.

Control excess runoff and erosion.

What is water harvesting?

Water harvesting means collecting runoff from a particular area. This water can then be:

- Taken directly to a field where crops can use it (this is called **runoff farming**).
- Stored for future use by crops, livestock or people (this is covered in this module and ► *Module 12*).

Most farmers focus their attention on improving water, soil and crop management on their individual fields and in the short term – the day-to-day management for their current crop. They rarely invest in ways to harvest water from nearby areas and bring it to their fields.

Water harvesting is most useful in semi-arid and dry sub-humid areas. In these areas, there is often not enough rainfall to support a crop. People and animals may go short of water too. It makes sense to try to capture water and store it until you need it.

Water problems may occur in wetter areas too. In these places, they are likely to be caused by too little water sinking into the soil, and too much running off. It is probably better to solve these problems through soil moisture management (► *Module 10 Managing rainwater*) than by trying to bring in water from somewhere else.

Watersheds or catchments

Think of a small river in your area. Draw a map showing this river and all the smaller streams that drain into it. Now think of the highest places (e.g., tops of hills, mountain peaks) around that river and the streams. Draw a line joining all the highest points from where rainwater will flow into streams and then into the river. The area inside the line is called the **watershed** or **catchment**.

Big rivers have large watersheds, and small rivers have smaller watersheds. Each of the smaller streams also has its own watershed, where rain falling will end up in that stream. These smaller watersheds are sometimes called **sub-watersheds** (or **sub-catchments**) (*Figure 11.1*).

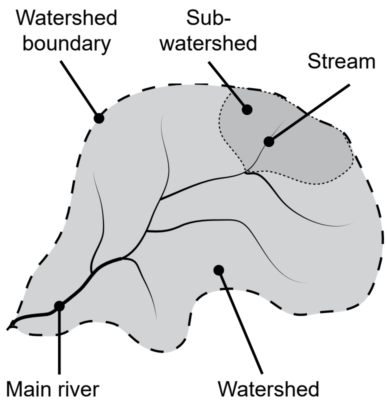


Figure 11.1. Watershed words

Working together

When managing water, it makes sense to manage it sub-watershed by sub-watershed. That means all the farmers in one watershed need to work together to decide how to manage their water.

11

It may be difficult for one farmer to harvest water alone. To be effective, several neighbours, or even the whole village, may have to work together. That requires organization and a long-term view. There are several reasons for this:

- **Workload and cost.** The construction work and costs may be too much for one person or family to manage.
- **Land ownership.** The land where the water is harvested may belong to someone else, or it may be communal land. So too may be the land where canals or storage ponds are to be built.
- **Community decisions.** Planting trees or restricting grazing may need decisions from the village authorities, and everyone's cooperation. In addition, one person's efforts to harvest water may affect his or her neighbours. There may be benefits to share (e.g., there is more water available in the soil for growing crops). Or there may be costs to share (e.g., a bund may break and create a gully across the neighbour's land). Farmers upstream should not harvest all the water, leaving those downstream without a drop.
- **Scale.** Some water control measures, such as building terraces and planting forests have to be done on a large scale if they are to be effective.
- **Timeframe.** Many water harvesting measures take several years to build, and it takes more time before the full benefits are seen.

You and your community should plan water harvesting in an integrated way to make sure you have water for all your various needs. For example, you may use in-field water harvesting (below) to supply water for your crops, a water tank (► *Module 12 Harvesting water for people and livestock*) for your livestock, and a well for your family's use.

► *Module 2 Improving land management* for ideas on how to plan water-harvesting schemes in a participatory way. It is important also to work with the local body responsible for drawing up land use plans.

If it's not possible to work with neighbours or with the village as a whole, you can use some small-scale water-harvesting techniques by yourself.

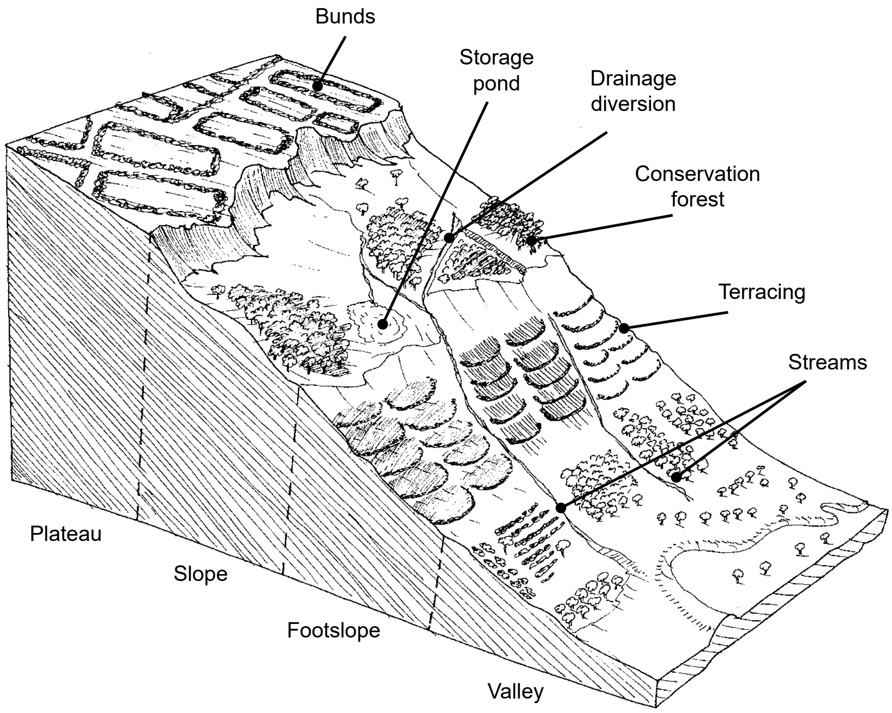


Figure 11.2. Example of an integrated water storage system along a sub-watershed.

Designing a water-harvesting scheme

A water-harvesting scheme may consist of up to three parts: a **catchment area**, a **storage area**, a **cultivated area**.

Catchment area

When we harvest water, we capture water in one place, and take it to another one. The area where it is captured is called the **catchment area**. For example, if you collect water from a roof and lead it into a tank next to your house, the roof is the catchment area. If you build a dam to collect water from an area of bare rock, and lead it to your fields, the rock is your catchment area.

For a catchment area, you can use a piece of land which you leave deliberately uncultivated. Unlike in your fields, you want as much rain to run off it as possible.

Catchment areas are easy to visualize in hilly, steep areas, and where runoff and water erosion are major problems. But in flat areas, the boundaries of a catchment area can be hard to see.

Storage area

A **storage area** is where you hold the harvested water until it is needed. You can store water in a reservoir or a pond, then use it for watering crops or animals. If you collect water from your roof, you probably store it in a tank or underground cistern. You may also bring water directly from the catchment area into the cultivated fields. In that case, your storage area is the soil itself in your cultivated area (see below).

Cultivated area

The **cultivated area** is where you grow crops using the water you have stored.

Planning to harvest water

What do you want to use the water for? For yourself and your family? For your animals? Or for your field crops? The answer will determine the type of water harvesting system you build.

To begin with, walk around the watershed with the other farmers to look at how you use and manage your land. This will help you, and the others, think of ways to improve your way of managing water, and choose places where to collect and store water.

You need to consider these things when planning a water-harvesting system:

- Climate
- Land uphill and downhill
- Crops
- Soils
- Topography (hills and valleys)
- Socio-economic factors.

Climate

Water harvesting is most suitable for semi-arid and dry sub-humid regions. In general:

- **Store water in the soil** in semi-arid areas where there is 200–400 mm of rain a year.
- **Store water in small structures** such as dams and tanks in dry sub-humid areas (400–800 mm of rain).

Land uphill and downhill

Check the land use, soil cover and erosion (► *Module 2 Improving land management*) both uphill and downhill of the potential sites for the catchment and the area where you will use the water. Check the soil type, slope, vegetation cover, land use and degree of erosion.

You do not want to harvest water from an area that is being eroded heavily: the erosion could damage the dams or channels you build, and silt could clog up the reservoir and pollute the water.

You should protect the catchment area from erosion uphill. For example, you could plant trees, or put in erosion-control measures (such as bunds and cutoff drains) to avoid sudden flash floods from damaging the water-harvesting scheme.

► *Exercise 2.1 Resource mapping.*

► *Exercise 2.2 Transect walk.*

Crops

Runoff farming is best for crops that need little water, grow quickly, have deep roots, and tolerate drought. This will minimize the risk of crop failure if the rains fail. The crops should also tolerate waterlogging, especially if there is no way to drain excess water away.

Suitable crops include:

- Sorghum (resistant to waterlogging).
- Other cereal crops (e.g. millet, maize, wheat), safflower and groundnuts (if drainage is good).
- Fruit trees (e.g., citrus, pawpaw, banana), leguminous trees (e.g., *Leucaena, Sesbania*) and woodlots (e.g., eucalyptus).
- Fodder grasses (e.g. Napier grass, Bermuda grass), and local grasses to restore denuded grazing land.

Runoff farming can also be used for crops that are less tolerant to drought and waterlogging, such as beans, cowpeas, green grams and black grams. Use runoff farming for these crops only if you already know how to grow them, and how to deal with problems such as water shortages and waterlogging.

► *Exercise 11.1 Crop water needs.*

Soils

Check the soils both in the catchment area and the area you want to cultivate.

A good area for **cultivation** has a soil with a medium texture (such as a loam), with no crusting and a medium infiltration rate (10 to 20 mm/hour).

The soil should be reasonably fertile, preferably with a lot of organic matter. It should be deep enough (1 to 2 m) to hold a lot of water. The surface should be level so that water spreads out evenly on the field. You may have to add organic matter to restore the soil health, and you may have to build bunds, cutoff drains, and so on to protect it from erosion.

A good **catchment** area has a compact, heavy, clayey soil where water sinks in only slowly. Unlike in the cultivated area, a surface crust is a good thing here. A soil that cracks when it dries is bad. Bare rock and places with thin soils also make good catchment areas.

► *Exercise 2.2 Transect walk.*

► *Exercise 4.3 Assessing soil structure.*

► *Exercise 4.5 Measuring how fast water sinks into the soil.*

► *Exercise 5.1 Observing soil organic matter.*

Topography (hills and valleys)

The cultivated area should be as flat as possible. If it is on a steep slope, consider using terraces and bunds to reduce the slope of the cultivated area.

The catchment area should be on a slope so water collects at the bottom end and can be channelled to the cultivation area. It must be uphill from the cultivated area, otherwise water will not flow from one to the other.

► *Exercise 2.2 Transect walk.*

Socio-economic factors

When planning a water harvesting scheme, you will need to consider a whole host of socio-economic factors. They include:

- How much labour is available?
- Who owns and controls the land and water?
- Is it possible to buy the inputs needed for construction and for growing crops, and can the crops be sold for a profit?
- What types of equipment are available – hand tools, animal-drawn or mechanical equipment?
- Are the farmers suitably organized?

► *Module 2 Improving land management.*

How to harvest water for crops

There are many ways of harvesting water and using it for growing crops.

- You can harvest water in the same field as you grow the crops (this is called **in-field water harvesting**)
- Or you can harvest the water somewhere else, then bring it to the field through channels or pipes (this is called **external catchment water harvesting**).

For the smallest in-field water harvesting, the catchment area (where you harvest the water) is between 1 to 10 times the size of the cultivated area (where you grow the crops). The cultivated area for any one catchment is generally up to 100 m^2. ► *Exercise 11.4* for how to calculate how big the catchment area should be.

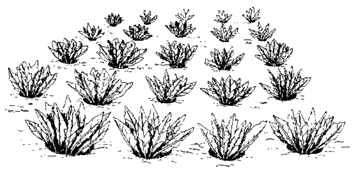


Figure 11.3. Planting pits

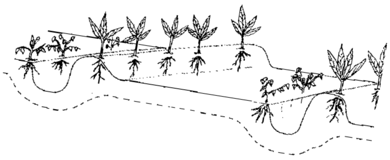


Figure 11.4. Contour ridges

Figure 11.5. Contour bunds

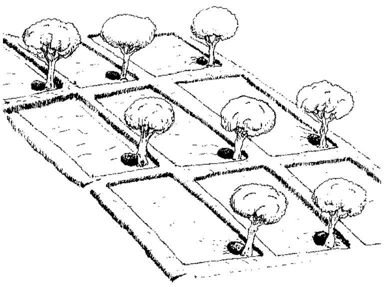


Figure 11.6. Negarims

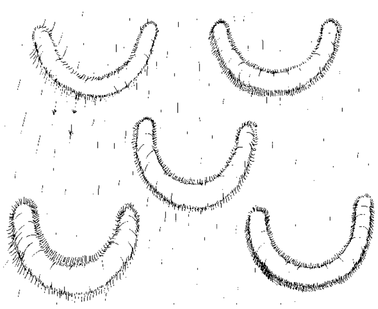


Figure 11.7. Semi-circular (or half-moon) bunds

In-field rainwater harvesting

There are many ways to harvest water in-field (or "in-situ"):

- **Planting pits.** The simplest method of water harvesting is using planting pits, or **zaï**. These are small holes, about 10 to 15 cm deep, filled with a mixture of soil and manure. Cereal crops (e.g., sorghum, millet or maize) are usually grown in the pits. Water collects in the holes, sinks into the ground, and is held in the soil by the organic matter (► *Figure 11.3*).
- **Contour ridges** are small earthen banks, built along the contour lines. They have a furrow on the uphill side which collects water from an uncultivated strip between the contour ridges. Cereal crops are usually planted on the ridges, and legumes on the upstream side of the furrows (► *Figure 11.4*).
- **Contour bunds** for trees are like contour ridges for crops, but they have pits instead of a continuous furrow to catch water. Trees are planted next to each pit.
- **Negarims** are small, diamond-shaped basins closed by low earth bunds. They are often used to plant trees such as pawpaw and citrus. At the lowest corner of each basin is a pit to collect water. A tree is planted next to each pit.
- **Semi-circular bunds** are earth bunds in the shape of a semi-circle or half-moon. They are laid out in staggered rows, with the arms pointing uphill and the tips lined up along the contour. They can be small or big: from 4 m to 60 m across. Large semi-circular bunds are used to rehabilitate rangeland and produce fodder crops.

External catchment water harvesting

External catchment water harvesting schemes take water from a catchment area outside the field. The catchment area might be a road, an area of bare rock, a compound, a school playground, or some other area where no crops are grown and where the ground absorbs little water.

You can store the water in a pond or tank, or lead the water directly into the field:

- **Storing water in a pond or tank.** You may be able to use the water for family use and for animals as well as for your crops. ► *Module 12 Harvesting water for people and livestock* for ideas on how to do this.
- **Leading water directly into the field.** You can use furrows to channel the water to the crops, allow the water to flow into basins or ditches to hold the water until it sinks into the soil.

Calculating the size of your catchment area

In ► *Module 10 Managing rainwater*, you worked out how much extra water your crop needs. Now you need to work out how large your catchment area (where you harvest the water) has to be to supply that much water.

The size of your catchment area depends on several factors:

- The amount of extra water you need (► *Module 10*).
- The amount of rain you expect (use the average seasonal rainfall).
- The percentage of water that runs off.
- The size of the area you want to cultivate.

Here's how to calculate the size of your catchment area:

1. Work out the amount of extra water (in millimetres) you will need for your crop (► *Module 10*).
2. Estimate the amount of rain (in millimetres) you expect in the growing season. You can use the average rainfall during the growing season.
3. Estimate the amount of water that runs off (► *Table 11.1*).
4. Use the following equation to calculate the size of the catchment area:

Relative area	=	Extra water needed	/	(Rainfall x Percentage of rain that runs off x 0.75)

Why do we multiply by 0.75 in the equation above? Because some water is always lost: it evaporates or percolates deeply into the ground, so does not reach the crop.

5. Multiply the relative size of the catchment by the size of your cultivated area. This will give you the size of the catchment area you need.

Size of catchment area	=	Size of cultivated area	x	Relative area

Table 11.1. What percentage of rain will run off from a catchment area?

On this type of land…	…this percentage of the rain is likely to run off
Sandy soils, gentle slope (<2% slope)	10%
Clay soils, steep slopes (10–30% slope)	50%
Asphalt road, bare rock	70–80%

Example (crops)

You have a field where you want to grow maize. Your area gets about 500 mm of rain in the growing season. You work out that you will need an extra 300 mm of water to get a good crop. You can use a gently sloping clayey area just uphill from the field to harvest water. How big should this catchment area be?

After checking *Table 11.1*, you estimate that about 30% of the rain that falls on the catchment area will run off. So the percentage of the rain that is likely to run off is 30%, or 0.3.

You calculate as follows:

Relative area	=	300 mm / (500 mm x 0.3 x 0.75)
	=	300 / 112.5
	=	2.67

Your catchment area should be about 2.67 times bigger than your cultivated field.

► *Exercise 11.4 Calculating the size of a catchment area.*

Catchment areas for trees and grasses

It is difficult to calculate the catchment area for **trees** because little is known about how much water various tree species need. Different types of trees need different amounts of water. And trees grow slowly over many years, so their water needs change.

As a rule of thumb, a trees roots cover about the same area of ground as its branches (its "canopy"). When you are planting trees, work out how big you expect the tree to grow so you can space them accordingly. Depending on the type of tree, make the catchment area between 10 and 100 m^2 per tree.

You might want to plant two seedlings in each catchment area to begin with, then remove one if there is not enough water for both.

For **rangeland and fodder grasses**, make the catchment area 2 or 3 times bigger than the area where you plant the grass.

Controlling erosion

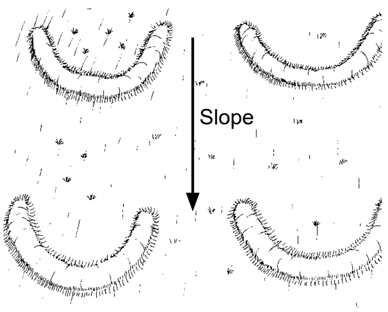
The soil can hold only a certain amount of water, and crops can use only the water that they can reach with their roots. If there is too much water (for example, during a heavy storm or if your catchment areas are too big), the following can happen:

- The water may run off the surface, carrying topsoil away with it.
- The water may overtop or breach bunds, washing them away and starting a gully.
- The water may stay on the surface, causing waterlogging.
- The water may sink deeper down into the soil, out of reach of the plant roots, and carry nutrients away with it.

Here's how to avoid these problems:

- Do not make your catchment areas too big.
- Make sure that your bunds and other structures are big and strong enough to handle a lot of water. Bunds made of stone let some water through, so are less likely to be washed away by water building up behind them.
- Space catchment basins close enough together, and stagger the rows so that excess water cannot flow around or between them.
- Make sure contour bunds actually follow the contour lines. If there is a low point, water will accumulate there and may break through the bund.
- Use cross-ties perpendicular to the contour bunds to prevent water from flowing along the bund to the lowest point.
- Provide an escape route for excess water. For example, build a spillway around a dam, and divert excess water into a natural waterway. Good drainage is especially important on clayey soils and if you grow crops that cannot tolerate waterlogging.
- On steeper slopes you can make ridges slope gently downwards from the contour line (at a slope of 0.25%), rather than along the contour itself (▶ *Figure 11.10*). That allows the extra water to run into a drain. This drain should not be longer than 400 metres, or it will end up carrying too much water and may turn into a gully.
- If a lot of water washes downhill from above, dig a cutoff drain or diversion ditch just above your water harvesting scheme to divert the surplus water away from your fields. The cutoff drain leads water into a natural waterway. Make the cutoff drain about 0.5 m deep, 1.0 to 1.5 m wide, and with a gradient of 0.25%.

Basins too far apart, and allo water to flow downhill between them



Correct pattern for basins: water cannot flow straight down the slope

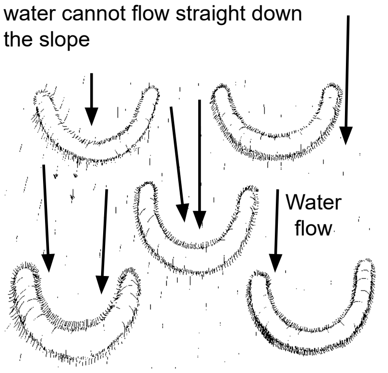


Figure 11.8. Wrong and correct spacing and alignment of micro basins

Figure 11.9. Draiinage channels should be gently graded and planted with trees and grass to stop them from being eroded

Maintenance

Keep your water harvesting scheme well maintained. This is essential for the scheme to work well and to avoid a disaster if it rains heavily.

Where a water-harvesting scheme involves several farmers, strong organization is needed to make sure that everyone contributes to the work and expense of maintenance.

These types of maintenance may be needed:

- Keep the catchment area free of weeds and other vegetation. This ensures that as much water as possible is harvested.
- Remove sediment from channels and ponds.
- Maintain and repair bunds and tied ridges.

► *Exercise 11.3 Review of existing water harvesting systems.*

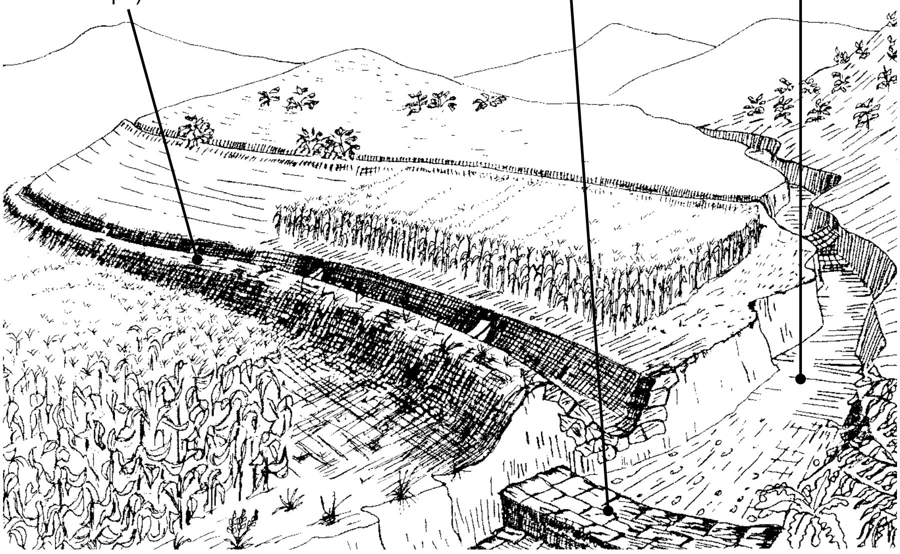


Figure 11.10. Graded bund

The graded bund in the foreground leads to a natural drainage channel. A checkdam protects the channel just below where the bund joins it

Exercise 11.1 Crop water needs

Learning objectives

Understand what affects the amount of water a crop needs.

Determine the water needs of different crops.

Timing

During the cropping season.

Preparation

Collect information from a nearby research station about the water requirements of the main crops farmers grow.

If this is not possible, check ► *Tables 10.3* and *10.4* for the amount of water the crops should need.

Duration

1.5 hours.

Materials

Paper and pens, large sheets of paper, marker pens; ► *Tables 10.3* and *10.4*.

Steps

Plenary discussion (45 minutes)

1. Discuss the following questions:

- What aspects of the weather affect the amount of water the crop needs? How? List them on a large sheet of paper.
- How much water does the crop need just after planting? (50% of the maximum). While it is growing? (50–100%). In the middle of the season? (100%). Late in the season? (100% for crops that are harvested fresh, and 25% for crops that are harvested dry).

Group discussion (45 minutes)

2. Divide the participants into groups of 4–5 people.
3. List the main crops grown in the area. For each crop, show the average sowing dates and length of the growing season.
4. Ask each of the groups to work out the water needs for three or four crops, using the method given in ► *Module 10*.
5. Ask each group to list the crops in order, from the lowest to the highest water needs.
6. Ask each group to summarize its findings and present it to the other groups.

Questions to stimulate discussion

- Which crop species and varieties are better suited to dry areas?
- When (at which stage) is a fully-grown maize crop most "thirsty"?
- Under what circumstances might the crop use less water? Will this affect the crop growth and yield?

Exercise 11.2 Water balance in a field

This exercise helps farmers understand what happens to water in the field, and how much there is stored in the soil.

Learning objective

Understand the water balance in a field.

Timing

Before starting a field experiment on water management; during the dry season, or better, in the preceding wet season.

Preparation

–

Duration

1.5 hours.

Materials

Paper, pens

Steps

1. Divide the participants into small groups of 3–5 people.
2. Describe the following situation to all groups: "We are in a maize field. The soil can hold a maximum of 50 mm of water. At the moment it holds 40 mm. Then it rains during the night, and 20 mm of rain falls." What happens in the following situations?

Situation 1

You have applied mulch and used planting pits to stop water from running away. All the water stays on the land.

- How much water is there now in the soil?
- How many millimetres of water will drain through the soil and go into the groundwater?

Situation 2

You have not applied any mulch, and there are no planting pits. Half the rain runs away.

- How much water is there now in the soil?
- How many millimetres of water will drain through the soil and go into the groundwater?

3. Ask the groups to discuss:

- If the crop needs 5 mm of water per day, how many days will it survive with if it uses this full amount?
- What happens in reality? How many days will the crop really survive?
- What is the difference if 20 mm of rain falls in 10 minutes or in 10 hours?
- What other things might affect how much water runs off?
- What would happen if the crop roots were deeper?

4. Ask the groups to report on their discussions to the plenary. Facilitate a full-group discussion on the water balance in the field.

Questions to stimulate discussion

- When does water percolate deeply? Where does it go? Is this good or bad? How could we reduce the amount of percolation? What affects how fast the water percolates through the soil and into groundwater?
- Is the runoff water lost? Where does it go? How can it be collected?
- How do we optimize the amount of water the crop transpires? How can we reduce water stress?
- Are water and the uptake of nutrients linked? How can we reduce the loss of nutrients?

Exercise 11.3 Review of existing water harvesting systems

This exercise uses a "ballot-box" method to test farmers' knowledge of land and water management. The farmers check existing water harvesting systems, and focus on constraints and opportunities for improvements.

Learning objectives

Review knowledge of land and water management.

Review existing water harvesting systems.

Identify constraints and opportunities for improvements.

Timing

When discussing water harvesting.

Preparation

Visit the field with a few key farmers to identify places and topics for the ballot-box questions. Find a route that passes the places you have identified.

Develop questions on the topics that are relevant in each place. For each place, write the problem you have identified, its causes and suggestions for improvements.

Prepare the ballot-box boards and place them along the route.

Prepare cards with a group number for each group of farmers.

Duration

3 hours.

Materials

Pieces of cardboard or folders, tape, rubber bands, marker pens, string, large sheets of paper, bamboo or wooden sticks, community map (if necessary) (► *Exercise 2.1 Resource mapping*).

Field exercise

1. Divide the participants into small groups of 4–5 people.
2. Describe the route and explain how to do the ballot box exercise (see below).
3. The small groups walk along the indicated route. Make sure that each group does the exercise separately – if necessary, start the groups off at 10-minute intervals.
4. On the way, the participants will find various boards (mounted on trees or on a stick in the ground), each with a question. Each question relates to a specific situation in the field.
5. Each group discusses the question and selects an answer from the three options (A, B or C) written on the board.
6. Each group drops a card with their group number on it in the pocket or box marked A, B or C.
7. The group then goes on to the next question, and so on until they have reached the end of the route and answered all the questions.

Plenary discussion

8. Remove all the ballot boxes from the field.
9. Open and discuss them one by one, reminding the participants about the location in the field and type of problem posed.
10. Read the first group's answer to the first question, and ask its members why they have selected that answer. Ask the other groups to comment.
11. Write down on a large sheet of paper the problems identified, their causes and possible solutions.
12. Read the answer of the second group for the second question and ask its members why they have selected that answer. Ask the other groups to comment.
13. Proceed in the same manner until the last question.

Guidelines for ballot box questions

The ballot box test is a field-based test, so make sure that the questions relate to the field situation. Write them in such a way that they can be answered only by observing what is in the field. If necessary, mark the thing you are asking about (for example, tie a piece of string to it from the question board).

When choosing places and questions, find the cause of the problem, then think of two other possible answers. These other answers may also be (partly) correct, or they may be wrong.

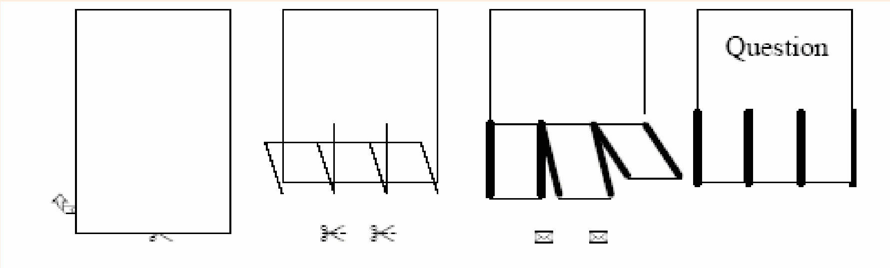
You can also use this method to design tests of other subjects, such as crop growth and soil health.

Making the ballot boxes

- Make a ballot box for each question (▶ *Figure 11.11*).
- Place the ballot boxes in the field.
- Prepare cards with a group number for each group.

Questions to stimulate discussion

- What did you learn from this exercise about how to manage water for crops?
- Did the questions cover most of the problems in the area?
- Were there questions about unfamiliar topics? What are these topics? Would you like to learn more about them?



Fold a flap of paper up | Cut slits | Tape sides closed | Write question on top of paper. Hang the ballot box in a sitable place

Figure 11.11. Making a ballot box

Box 11.1. Examples of ballot box questions

Runoff farming and soil moisture management

1 How can you increase the amount of water stored in this field?

a Increase the plant spacing

b Increase the soil organic matter

c Compact the soil

2 Why is this crop suitable for this farming system?

a It grows quickly and resists drought

b It tolerates salty soil

c It needs a lot of water

Location problems

3 Why are these crops short of water?

a The soil is shallow

b The slope is steep

c Weeds take water away from the crop

Design problems

4 Why is this water harvesting system not well designed for the crops grown?

a There is not enough rainfall

b The slope is too steep

c The catchment area is too small

Construction problems

5 Why are these bunds breached?

a There is no drainage system to take away excess water

b Animals have damaged the bunds

c The bunds do not follow the contour line

Maintenance problems

6 Why is water not uniformly distributed in this field?

a There are no tied ridges to hold water

b The bunds have been broken

c The soil is shallow

7 How can we increase the amount of water harvested in this catchment area?

a Remove the weeds

b Make the slope steeper

c No solution

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Exercise 11.4 Calculating the size of a catchment area

Learning objective

Calculate the size of a catchment area for various crops.

Timing

Any time when discussing water harvesting.

Preparation

–

Duration

3 hours.

Materials

Paper, pens, pocket calculators (if available).

Steps

1. Explain that a farmer has a 2-ha field with sandy loam soil and gentle slope. She is thinking of planting either maize or millet. She knows the rainfall is not eought to support these crops, so she is planning a catchment area to harvest water for her field. How big does the catchment have to be for each of the crops? Ask the groups of participants to calculate the size of a catchment for the fields and crops using the information in ► *Table 11.2*. (If necessary, change the climate, crop and soil types to match those in your area.)

Participants should use these equations:

Extra water needed = Crop water needs – Seasonal rainfall

Relative area = Extra water needed / (Rainfall x Percentage of rain that runs off x 0.75)

Size of catchment area = Size of cultivated area x Relative area

Results:

	Extra water needed	Relative area	Catchment area needed
Millet	600 – 500 = 100	100 / (500 x 0.1 x 0.75) = 2.67	2 ha x 2.67 = 5.33 ha
Maize	800 – 500 = 300	300 / (500 x 0.1 x 0.75) = 8	2 ha x 8 = 16 ha

2. Discuss why the catchment area for maize is larger than the catchment area for millet. (Because millet requires less water.)
3. Ask the groups of participants to calculate the size of a catchment for the situations in ► *Table 11.3*. (Again, if necessary, change the climate, crop and soil types to match those in your area.)

Results:

	Extra water needed	Relative area	Catchment area needed
Millet	600 – 500 = 100	100 / (500 x 0.15 x 0.75) = 1.78	2 ha x 1.78 = 3.56 ha
Maize	800 – 500 = 300	300 / (500 x 0.5 x 0.75) = 1.6	2 ha x 1.6 = 3.2 ha

4. Discuss why the catchment area for millet is larger than the catchment area for maize. (Because of the soil type and slope.)

Questions to stimulate discussion

- Which crop would the farmer be better advised to grow? Maize or millet?

- What happens if the actual rainfall is much higher than the amount she expects? How can she deal with this problem?

Table 11.2. Example of calculating catchment area required: gentle slopes

Crop	Crop water needs	Rain during season	Soil type	Slope	Percentage runoff	Cultivated area
Millet	600 mm	500 mm	Sandy loam	Gentle slope (2%)	10% (= 0.1)	2 ha
Maize	800 mm	500 mm	Sandy loam	Gentle slope (2%)	10% (= 0.1)	2 ha

Table 11.3. Example of calculating catchment area required (moderate and steep slopes)

Crop	Crop water needs	Rain during season	Soil type	Slope	Percentage runoff	Cultivated area
Millet	600 mm	500 mm	Sandy loam	Moderate slope (5%)	15% (= 0.15)	2 ha
Maize	800 mm	500 mm	Clay	Steep slope (30%)	50% (= 0.5)	2 ha

Module 12. Harvesting water for people and livestock

This module focuses on harvesting and storing water for people and animals. You can use some of the same techniques for crops too: for example, if your water tank is big enough, you can use it to irrigate a vegetable garden or field crops.

Learning objectives

After studying this module, you should be able to:

Match the amount of water available with the amount you need for your family and animals.

Work out how big a storage structure (tank or pond) you need for your family and animals.

Select ways to store and use rainwater.

Collecting clean water

There are many ways to collect water and keep it clean so people and animals can drink it. Here are some of them.

Harvesting water from rooftops

Put a gutter on your roof to catch rainwater and lead it into a tank next to your house. This works well with roofs made from metal or tiles.

- Put wire screens on all inlets and overflows.
- Put a silt trap on the inlet pipe.
- Let the first heavy shower wash the dirt from the roof before you start collecting water.
- Do not put water from other sources into your rainwater tank.

Ponds and tanks

Use dams and channels divert water from a catchment area into a deep pond or tank. Make the tank deep to minimize evaporation, and line it with plastic, cement or clay if possible to reduce percolation.

- Put silt traps on the inlet channel.
- Build a fence around the water pan to keep animals and children out.
- Provide a tap for domestic use and a water trough for livestock downstream from the pan.

Rock catchments

Build a dam across an area of bare rock to catch rainwater behind it.

- Build a fence around the catchment to keep animals and children out.
- Clean the runoff area before the rains.
- Provide a tap for domestic use and a water trough for livestock downstream from the catchment.

Subsurface dams and sand dams

A **sub-surface dam** is an impermeable wall built across a dry, sandy riverbed. The dam stops water flowing underground, so it accumulates behind the wall. Dig into the sand, down to the solid rock underneath, then build the dam on top of the rock. That prevents water from leaking out underneath the dam.

Table 12.1. Water needs per person

Each person needs this many litres of water a day for…	Litres a day
Drinking	5
Cooking	10
Latrines (depends on the type of latrine used)	0–20
Washing and bathing	15
Total	**30–50**

You can build a **sand dam** (a wall on top of the sub-surface dam) to trap new sand that comes down the riverbed when it floods. The sand holds water behind the dam.

- Dig a well behind the dam to tap the water that is trapped there.
- Raise the sand dam when needed to trap more sand and water.
- Build a fence around the well to keep animals and children out

How big should your storage pond or tank be?

If you want to build a tanks or ponds to collect water to use during the dry season, you need to know how big they should be. You don't want to run out of water halfway through the dry season. But you also don't want to make the storage structure too big (which would be wasteful and expensive).

You may get water from several different sources. For example, perhaps you use a well for your drinking water, and river water for washing. Take these sources into account when you plan your water harvesting scheme.

The size of your pond or tank depends on several things:

- **Water needs**: how much water you need during the dry season for people and for livestock.
- **Water supply**: how much water you can collect during the wet season.
- **Water losses**: how much water is lost from the storage pond or tank.

We will look at each of these in turn.

Water needs for people

People generally need about 30–50 litres each a day (► *Table 12.1*).

To work out how much water your family needs during the dry season, make the following calculation:

If you use water to flush your latrine:

Number of people in family	x	50 litres	x	Number of days water is short	=	Total water needs

If you do not use water for your latrine:

Number of people in family	x	30 litres	x	Number of days water is short	=	Total water needs

Example

You have a family of six people. You have a pit latrine, so do not need water to flush your toilet. The dry season lasts 200 days. You will need the following amount of water for your family:

6 people	x	30 litres	x	200 days	=	36,000 litres
					=	36 m^3

Divide the answer by 1000 to get the number of cubic metres.

You will need a 36 m³ tank to hold enough water to supply your family's needs during the dry season.

► *Exercise 12.1 Water for people and livestock.*

Water needs for livestock

Different animals need different amount of water. ► *Table 12.2* gives a rough guide.

To work out how much water your animals need during the dry season, multiply the number of each type of animal you have by the amount of water it needs. Then add all the answers together to get the amount of water needed every day.

Now multiply this amount by the number of days that water is short. That gives you the total number of litres your animals will need during the dry season.

Table 12.2. Water needs of different types of livestock

This type of animal…	…needs this many litres of water a day
Camel	50
Cattle	25–35
Sheep	5–15
Goat	5–15
Donkey	16–20
Chickens	15–20 per 100 birds

Example

You have 5 cattle, 10 sheep and 100 chickens. The dry season lasts 200 days. You will need the following amount of water for your animals:

5 cattle	x	30 litres	=	150 litres
10 sheep	x	10 litres	=	15 litres
100 chickens			=	15 litres
Total				265 litres/day
265 litres/day	x	200 days	=	53,000 litres
			=	53 m^3

You will need a 53 m³ tank to hold enough water to supply your animals' needs during the dry season.

► *Exercise 12.1 Water for people and livestock.*

Water supply: How much water you can collect

To work out how much water you can collect, you need to know:

- The size of the catchment area (in square metres).
- The average seasonal rainfall (in millimetres).
- The type of surface in the catchment area (sand, clay, rock, asphalt, etc.).

Here's the equation:

Amount of water to store (litres)	=	Size of the catchment area (m^2)	x	Seasonal rainfall (mm)	x	Percentage runoff (%)

► *Table 11.1* for the percentage runoff from different types of catchment area surfaces. You can also find estimates of these "runoff coefficients" in text-books.

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If you cannot collect enough water from one collection area to supply all your needs, you may have to make a number of ponds or tanks to harvest water from several different areas.

Example

Your area gets 500 mm of rain in the wet season. You use an asphalt road as your catchment area. You measure it and find it is 450 m^2. The amount of water you need to store is as follows:

Amount of water to store (litres)	=	450 m^2	x	599 mm	x	70%
	=					157,500 litres
	=					157.5 m^3

You will need to build a tank to hold 157.5 m^3 of water.

For example, you might build a tank measuring 7 m long, 7 m across and 3 m deep:

7.5 m	x	7 m	x	3 m	=	157.5 m^3

The actual rainfall can vary a lot from year to year. There can be a lot more rain than usual, and it can come in a few heavy storms. So you should design your dams, channels and tanks accordingly: make them bigger and stronger than would be needed for the average rains. Construct a spillway or outlet to let excess water escape so it does not damage the structures.

Plus, the capacity of a pond or tank can get much smaller over time as silt builds up on the bottom. Make sure you design and maintain the reservoir to keep siltation to a minimum (► *Reducing water losses* below).

► *Exercise 12.2 Estimating runoff.*

► *Exercise 10.8 Soil cover to reduce erosion.*

Water losses

Your pond or tank can lose water through evaporation and through leaks or seepage. You should try to minimize the amount of water lost: the less you lose, the more you can use.

Here's how to calculate these amounts.

Losses through evaporation

Open ponds or tanks lose water as it evaporates into the air. How much? You can measure the evaporation rate by putting some water in a shallow pan and leaving it in the sun. ► *Exercise 10.2 Evaporation* for how to do this.

If you cannot measure it yourself, you can estimate the evaporation rate as 5 to 10 mm/day. That is normal for dry sub-tropical or tropical climates.

Multiply the number of millimetres lost through evaporation each day by the surface area of the pond (in square metres). That will give you the number of litres of water lost every day:

Water lost to evaporation (m^3/day)	=	Evaporation rate (mm/day)	x	Surface area (m^2)

Multiply the answer by the number of days in the dry season to get the total evaporation losses.

Of course, if you make an underground tank, or a cement tank with a lid, there should be very little evaporation.

Example

You find that 6 mm of water evaporates from your pan on a typical day. You plan your pond to be 7.5 m long x 7 m wide, so the surface area will be 52.5 m^2. The dry season lasts 200 days.

Water lost to evaporation (m^3/day)	=	6 mm/day	x	52.5 m^2
	=			315 litres/day
	=			0.315 m^3/day

Multiply the answer by the number of days in the dry season to get the total evaporation losses:

Total water lost to evaporation	=	0.315	x	200	x	63 m^2

Losses through seepage

It is harder to measure seepage, so you may have to make a guess:

- If the pond or tank is new and has no lining, you can assume the seepage losses to be the same as the infiltration rate of the main soil type (► *Table 10.2*). For example, clay has an infiltration rate of 1–5 mm per hour, or 12–60 mm a day. ► *Exercise 4.5* for how to measure the infiltration rate on your soil type.
- Your pond or tank will lose less and less water as tiny soil particles block up the channels and passageways in the ground. This usually happens fairly quickly after you fill it.
- If the groundwater level is higher than the base of the pond, the pond will lose very little water through seepage.
- If you line your pond or tank with plastic, cement or impermeable clay, it will also lose very little water through seepage.

Adding it all up

So how big should your tank be?

Add the amount of water lost to the water you need. That gives you the minimum size of the tank or pond you will need.

Minimum size of tank or pond	=	Water demand	+	Water losses

Compare the answer with the amount of water you are able to collect. If you can collect more water than you need, you are OK! Build a tank or pond big enough for your needs. You might want to make it a bit bigger so you have enough water in case the dry season is extra-long, or so you can use the additional water for irrigation or to water more animals. Don't make the structure too big, or it will cost too much to build and may never fill up.

If you find you can collect less than you need, you should consider ways of harvesting more water. Perhaps you can collect water from another catchment area.

Example

You estimate you will need 36 m^3 of water for your family and another 53 m^3 for your animals. You do not plan to use your tank to irrigate crops.

Your tank will be lined with impermeable clay, so after a few weeks you will not lose much water through seepage. You plan your tank to measure 7.5 m x 7 m, and to be 3 m deep. That gives a surface area of 52.5 m^2 and a total volume of 157.5 m^3. Will this be enough?

First, calculate how much water you will need for your family and your animals:

Total water demand	=	36 m^3	+	53 m^3
	=			89 m^3

Then calculate how much water will evaporate during the dry season (using the same information as in the examples above):

Water lost to evaporation in dry season	=	6 mm/day	x	52.5 m^2	x	200 days
	=					63 m^3

Then calculate the minimum size of your tank:

Minimum size of tank or pond	=	Water demand	+	Water losses
	=	89 m^3	+	63 m^3
	=			152 m^3

Your planned tank will hold 157.5 m^3. This is more than 152 m^3, so should be just enough to last through a normal dry season.

Reducing water losses

Reducing evaporation

How to reduce evaporation losses from a reservoir? Some suggestions:

- **Deepen the reservoir.** Small but deep ponds lose less through evaporation than large, shallow ponds. Make the reservoir deeper, and limit its surface area. Encourage farmers to deepen shallow water pans so they hold more water and lose less through evaporation.
- **Shelter it from the wind.** A dry wind blowing over a pond makes it dry out more quickly. If the pond is small, plant trees around it to act as windbreaks. Remove unproductive weeds growing on the surface to cut down transpiration.
- **Store water below the ground.** Put a cover on the tank, or store water in underground cisterns, or behind subsurface dams or sand dams.

Reducing seepage

Here are some ways to reduce losses through seepage:

- Compact the bottom and walls of the reservoir.
- Line the reservoir with plastic, a 10–20 cm layer of compacted clay, or cement (though this is expensive).

Reducing siltation

If your reservoir silts up, it will not hold any water! Here are some ways to keep siltation to a minimum:

- **Control erosion in the catchment area.** Use various erosion-control measures to keep silt from washing off the land and into the channels that feed into the reservoir. There are many ways to do this. ► *Module 11* for some ideas.
- **Build a silt trap.** This is a smaller pond or tank just upstream from the main reservoir. Water flows into the silt trap, drops its load of silt there, and then flows gently on into the main reservoir. Clean the accumulated silt out of the silt trap regularly (it is often fertile, so apply it to your fields).
- **Clean out the reservoir.** Clean out the silt from the reservoir regularly. Wait until the reservoir is empty to do this. Use the silt as fertilizer on your fields.

Exercise 12.1 Water for people and livestock

Learning objective

Determine the water needs of a household for domestic use and livestock.

Timing

When planning water harvesting measures.

Preparation

Prepare tables showing water needs of people and various animals (► *Tables 12.1* and *12.2*).

Duration

2 hours.

Materials

Common containers used for water: buckets and jerry cans of various sizes (5, 10, 20, 50 litres); 200-litre drum, water.

The amount of water each household needs depends on the number of people and the type and number of livestock. For a village, you can add together the water needs of all the people and animals to get the needs of the community as a whole. Knowing this is important when planning how to harvest water during the dry season.

Steps

1. Divide the participants into small groups of 3–5 people.
2. Ask the groups to familiarize themselves with how much each of the containers holds.
3. Ask the groups to work out how much water each of their households needs for all the people in them. (Note: people may find it easier to think in terms of how many 20-litre bucketfuls they need, rather than in terms of litres.)
4. Ask the groups to work out how much each household needs for their animals.
5. Ask how many days are "critical" in terms of water.
6. Ask the groups to work out how much water each household needs (for people and animals) to overcome this critical period.
7. Ask the groups to work out how much water the community as a whole needs during the critical periods.
8. Each group presents their estimates to the plenary.
9. Discuss the results.

Questions to stimulate discussion

- What determines how much water a household needs?
- How does the household size and composition affect its water needs?
- Supposing you have to work out the size of a reservoir to serve the community. What factors should you think of? How would you optimize the storage capacity of a reservoir?
- Just having enough water is not enough to keep people healthy. What else must you think of?
- Imagine the water source is a long way away. How much water will people use then?
- How much water do different types of animals use? How about milking cows and calves? In the wet and dry seasons?

Exercise 12.2 Estimating runoff

Steps

1. Measure the size of the catchment in square metres.
2. Determine how much rain (in millimetres) fell in the last storm.
3. Decide on the type of catchment and identify the runoff coefficient.
4. Estimate how much water will run off from the catchment using this equation:

Volume of runoff (litre) = Catchment area (m^2) x Rainfall (mm) x Percentage runoff (from *Table 11.1*)

Questions to stimulate discussion

- How can you increase the amount of water you can harvest during a storm?
- What happens if it rains so hard that there is more water than your tank or pond can hold? How can you get rid of the extra water?
- What happens if it rains less than you hoped? How can you make best use of the water you have?

Learning objective

Estimate how much water runs off a catchment area during a rainstorm.

Timing

Any time.

Preparation

Choose a catchment area such as a rooftop or road it should be possible to harvest water.

Measure how many millimetres of rain falls during a heavy rainstorm (► *Module 10*).

If you can, collect information on the percentage runoff for the type of surface in the catchment. You might be able to get this information from a nearby agricultural research station or district office. If not, use the figures in ► *Table 11.1* (or estimate the amounts based on this table).

Duration

30 minutes for the exercise.

Materials

Paper, pens, tape measure, rain gauge (if available), ► *Table 11.1* (percentage runoff for different surfaces).

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Module 13. Managing weeds

A weed is any plant that grows in the wrong place at the wrong time. Weeds smother crops. They shade them and consume nutrients and water, meant for the crop. And they may produce harmful chemicals that restrict the crop's growth. Uncontrolled, weeds can cut yields dramatically.

In eastern and southern Africa, striga (*Striga* spp., witchweed) and couch grass (*Cynodon dactylon*) are particularly harmful and hard to control. In other regions, spear grass (*Imperata cylindrica*) is a big problem. In pastures, livestock prefer to eat more palatable species, leaving weeds to take over the pasture.

Smallholder farmers spend a lot of time and energy weeding. They need to test and develop better ways to deal with weeds. This module describes how to help them do this.

Learning objectives

After studying this module, you should be able to:

Understand how 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.

Harmful effects of weeds

Most farmers know the harmful effects of weeds:

- Weeds compete with crops (including fodder and pasture crops) for nutrients, water, light, air and space. They reduce the yield and quality of the crop.
- Some weeds produce chemicals that harm the crop.
- Weeds may carry diseases and pests which attack crops.
- Some weeds are poisonous for humans or animals.
- Weed seeds can get mixed in the crop yield and with seed for the next crop.
- Dry weeds may pose a fire hazard.
- Weeds can clog rivers and irrigation and drainage channels.
- Weeds may reduce the value of land.
- Weeds in lakes and rivers (such as water hyacinth) affect fish, drinking water supplies and recreation.

Weeds compete with the crops for nutrients, water, light and space.

Benefits of weeds

Not all weeds are bad! They do have some benefits:

- They cover the ground and protect it from erosion.
- Deep-rooted weeds can bring moisture and nutrients up to the surface from depths where shallow-rooted crops cannot reach.
- Left in the field, dead weeds act as mulch and conserve moisture (► *Module 5 Using organic materials*, *Module 8 Conservation agriculture* and *Module 10 Managing rainwater*). (But be sure to kill weeds before they produce seeds, or remove them from the field to prevent the seeds from germinating.)
- Some (but not all) weeds can be used to make compost.

Not all weeds are bad!

If you do not control weeds, your crop yields are likely to fall

- Some weeds (such as amaranth) provide food for humans and fodder for animals.
- Some weeds repel insects, or host friendly insects and spiders which kill pests.
- Some weeds are related to crop species; scientists can use them for breeding purposes.
- When weeds die, they release nutrients that crops can use.
- Some weeds have beautiful flowers.

There are different ways to manage weeds

Managing weeds

It is impossible to eradicate weeds completely. So the farmer has to turn the weeds into friends, and manage them. At certain times you have to control the weeds to prevent them from competing with the crops – especially when the crop is still young and vulnerable.

Weeds that climb and suffocate the crop need to be controlled carefully. Weeds that grow tall rapidly may shade the crop's leaves and reduce its growth. Weeds with spreading roots take moisture and nutrients that the crop could use.

Some weeds need special attention. ***Striga*** grows on host plants (such as maize) in infertile soils. It produces lots of seeds that can lie dormant in the soil for many years. **Couch grass** and some other weeds spread through underground stems (called tillers or rhizomes). They grow fast, are hard to remove, and easily regrow when cut.

Weeding is a big job. For example, smallholder farmers in Zimbabwe spend more than 75% of their time from December to February battling weeds.

There are four basic ways to manage weeds: prevention, agronomic measures, mechanical measures, and chemicals.

Prevention

This means preventing weeds from growing in the first place:

- Use clean, uncontaminated crop seeds.
- Control weeds that grow around the field borders.
- Remove weeds from the fields before they flower and set seeds. "One year's seeding makes seven years weeding!"

Agronomic measures

Weed problems get worse if the soil is infertile, as there are fewer nutrients for crops to use. So maintaining a healthy, fertile soil is an important part of controlling weeds.

- Manage crop residues and manure.
- Make compost: 2–3 months of composting kills 70% of weed seeds
- Rotate crops or plant intercrops.
- Plant cover crops or use mulch to cover the soil.

► *Module 5 Using organic materials*, *Module 7 Managing plant nutrients* and *Module 8 Conservation agriculture* for more information.

Mechanical measures

This means physically cutting or removing weeds.

- Pull weeds out of the soil, or cut them by hand or with animal- or tractor-drawn implements. If they have not flowered and set seed, leave them on the ground as mulch. If they have set seed, use them for compost or fodder.
- Collect and burn problem weeds such as witchweed and couch grass.

Chemical measures

Although herbicides can be very effective in controlling weeds, they are expensive and may harm soil life and soil water quality. They may also damage useful plants in or around the field. Using herbicides needs special equipment and clothing, careful handling and storage, and specialist knowledge.

Different herbicides work in different ways:

- **Contact** herbicides kill only the parts of the plant that the herbicide touches. They act quickly, but the plant may be able to regrow from roots or tubers.
- **Systemic** herbicides are absorbed by the plant's leaves or roots, and can kill the whole plant.
- Different types of herbicides can kill different types of plants:
- **Selective** herbicides kill only certain types of plants. For example, 2,4-D kills only broadleaved weeds, but not grasses.
- **Non-selective** herbicides kill all types of plants. For example, Atrazine kills both broadleaves and grasses.
- Different herbicides must be applied in different ways, and at the right time:
- **Soil-applied herbicides** are applied to the soil, where the plant roots can take them up.
- **Pre-emergent herbicides** are applied to the soil before the crop emerges. They prevent young weeds from growing and weed seeds from germinating.
- **Post-emergent herbicides** are applied when the crop is already growing.

When to weed is as important as how you do it

When to weed

When should you weed? The timing is as important as the weeding itself.

Weeds cause the most damage while the crop is germinating and for several weeks afterwards. How long depends on the crop (► *Table 13.1*).

For maize, for example, it is important to control weeds in the first 4–6 weeks – until the maize plants have about 14 leaves. After this time, the maize plants will be big enough and the canopy dense enough to suppress most weeds. In area with low rainfall, that means weeding the maize field twice. In wetter areas, you should weed three times.

Table 13.1. How long do you have to control weeds?

For this crop…	…control weeds for this many weeks after sowing
Sorghum, field beans	4–5
Maize, sunflower	4–6
Ground-nuts	6
Cotton	6–8
Onions	12

Control weeds before they flower and spread their seeds

During the cropping season, it is best to weed when it is hot and dry. The weeds will dry out quickly and not regrow.

Controlling weeds does not mean getting rid of all weeds in the field – this is impossible. But it does mean making sure that the weeds do not shade the crop or take away its nutrients or water.

Weed the first time as soon as the crop emerges (if there are weeds in the field). Continue weeding for at least 4 weeks (for maize or sorghum) and at least 6 weeks for groundnuts and cotton (► *Table 13.1*).

Try weeding at different times to see what effect it has on crop yields. You can also test cover crops and other management practices to control weeds.

► *Exercise 13.1 Recognizing weeds.*

► *Exercise 13.2 Weed management trial.*

Economics of weeding

Is weeding worth it? Weigh these arguments:

- Weeding is hard work, and can take a lot of time and money, especially if there are many weeds and the crop is already at an advanced stage.
- You or your family may be able to earn more money elsewhere.
- If you have to hire workers, will the extra yield give you enough to pay them?

On the other hand…

- Done correctly, weeding can boost your yields substantially.
- Weeding is an investment in the future. If you don't control weeds, they will produce seeds that will cut your yields next year and the years after.

In most cases, destroying weeds before they set seed is profitable in the long run.

Couch grass

Couch grass (*Cynodon dactylon*) occurs in many areas where farmers have practised shallow ploughing. This grass spreads very quickly through underground stems.

Hand pulling. You can control couch grass by hand-pulling the plants and the underground stems. Remove as much of the plants as possible, then take them out of the field and burn them. Do not put them on a compost heap or feed them to animals. If the field has a lot of couch grass, you may have to use a herbicide.

Ploughing and harrowing. Repeated ploughing and harrowing during dry weather – twice in 6 hours – helps reduce couch grass problems. This drags the underground stems to the surface, where they dry out in the sun. But some stems may still regrow. Ploughing requires draught animals or a tractor, and it harms the soil structure and soil life, dries the soil out, and reduces the organic matter in the soil (► *Module 8, Conservation agriculture*).

Herbicides. If you are forced to use herbicides, choose one carefully, as relatively few are effective against couch grass. Herbicides can be expensive and hard to find, and may damage the soil life and crops, and pollute the water. Try to minimize the amount of herbicides you spray by hand weeding or ploughing.

Striga or witchweed

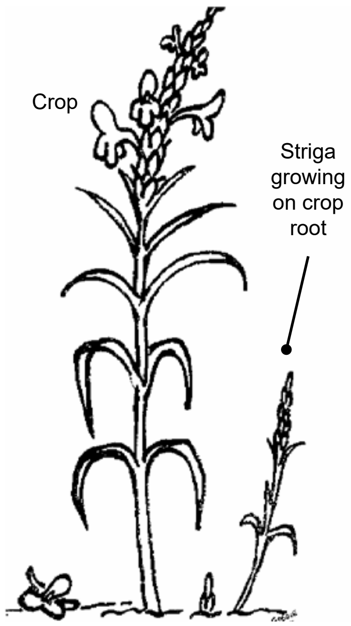

Figure 13.1. Striga is a parasitic weed of maize and other crops

Striga not only competes with crops, but also attacks them directly. It is a parasite (like a tick or a flea), which lives and grows on a host plant – such as maize. It attaches itself to the roots of the host plant, and sucks out its water and nutrients. It causes more damage to its host than any other weed.

There are two main striga species in Africa:

- ***Striga hermonthica*** is an erect plant with a strong, fibrous stem, up to 1 m tall. It has purplish, pink or white flowers, arranged in spikes about 15 to 45 cm long. It is common on heavier soils.
- ***Striga asiatica*** is much smaller: it grows up to 30 cm high. It has fewer, smaller leaves, and red flowers. It is common on light, sandy soils.

Both types of striga attack many species of the grass family, including maize, sorghum, finger millet, upland rice, sugar cane, Sudan grass and Napier grass.

Striga produces thousands of tiny seeds – up to 50,000 from just one plant. The seeds can remain dormant in the soil for many years, waiting for a suitable host plant. When it detects a host plant nearby, the seed germinates and attaches itself to the host's roots.

After 3 to 6 weeks underground, the first striga plants emerge above the surface. Not all the attached striga seedlings emerge. Many will still stay underground. About 3 to 4 weeks later, the striga plant flowers, and within 14 days produces seeds.

Symptoms of striga

You can see the first symptoms of striga damage even before the weed appears above the soil surface. Symptoms are similar to those caused by drought:

- Stunted growth
- Wilting or scorching (even if the soil is moist).
- Yellowing of the upper leaves.
- Barrenness (no setting of cobs or heads).
- Death of host plant before flowering, especially in highly infested fields.

Yield losses depend on the amount of striga and other stresses that affect the crop. They can be 30–100% for maize, and 20–50% for sorghum.

If you see striga, the soil is probably infertile

Remember

- Striga damage: stunted growth, wilting, yellow leaves.
- Yield losses worst when striga infestation occurs at the same time as other stresses.
- Early striga attacks cause more damage than later attacks.

Controlling striga takes time

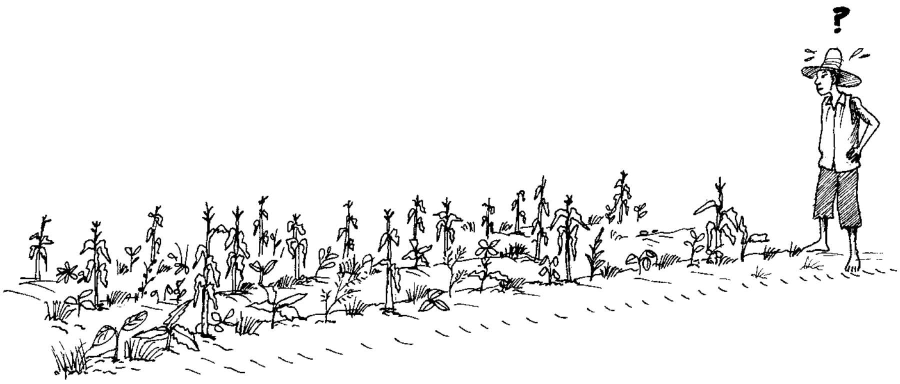

Figure 13.2. Striga is especially a problem on infertile soils

Controlling striga means you have to understand how striga grows and spreads

- A healthy crop resists striga better than one suffering from low soil fertility or diseases
- Striga problems are worst on soils that are infertile and low in organic matter. Striga can be controlled by increasing the soil fertility

How to stop striga from spreading

Striga's many tiny seeds can spread easily:

- On harvested maize cobs or sorghum heads. If these crop seeds are used for planting, striga can be carried to new fields.
- On farm machinery and tools.
- On animals. The seeds can stick to the fur or hair of animals grazing in harvested fields. Or animals may eat them: the seeds spread through their droppings.
- On people. Striga seed can stick to shoes and clothes.
- In water. Running water can carry striga seeds into other fields downhill, or into rivers which then deposit them along their banks.
- Here's how to stop the seed from spreading:
- Remove all striga plants before they flower.
- Collect maize cobs or sorghum heads directly to use as seed. Do not drop or thresh them in the field. Do the same for the seeds of beans, cowpeas, etc., that you plant as intercrops.
- Clean farm tools after working in fields that have striga.
- Do not graze livestock in fields with striga.
- Burn all uprooted striga weeds in a deep hole so the seed cannot spread. Don't throw them on roadsides or footpaths.

Controlling striga takes time and effort. It must involve all farmers in the community because the seeds can spread so easily.

Figure 13.3. Striga seeds spread easily on tools and clothing

How to control striga

You should try to reduce the amount of striga seeds in the soil, and the number of weeds in the field.

Improve soil fertility. Striga problems are biggest on infertile soils. Apply lots of organic matter to raise the fertility. This takes time, but after a few seasons the striga numbers should decrease tremendously.

Choose crop varieties that are tolerant to striga. In general, sorghum is more tolerant to striga than maize: sorghum yields suffer less than maize with the same number of striga in the field.

Weed or hand-pull striga before it flowers. This is the most effective control method, because it stops the striga from seeding. But it takes continuous weeding over many seasons to get rid of all the striga seeds in the soil.

Use trap crops. Some crops force striga seeds to germinate, but the striga cannot attach to them, so the weeds die, leaving the crop unharmed. These crops are called **false hosts** or **trap crops**. They include cotton, sunflower, sesame, soybean, peanut, bambara groundnut, pigeonpea, lablab, beans, cowpea and fodder legumes such as sesbania, leucaena, calliandra, crotalaria, Mucuna and desmodium. Some varieties are better than others at stimulating striga seeds to germinate. You can plant trap crops as intercrops, in crop rotations, or in improved fallows (see below).

Plant intercrops. You can intercrop maize or sorghum with another crop that covers the soil well, such as groundnut, cowpea, or sweet potato. Plant the intercrop at the same time as the main maize or sorghum. Fewer striga plants will emerge and flower. The striga will still affect the maize or sorghum, but you get the extra yield from the intercrop, and weeding is easier because fewer striga will emerge.

You can also intercrop maize with desmodium. You can use either silverleaf (*Desmodium uncinatum*) or greenleaf (*Desmodium intortum*). Desmodium is a legume, so fixes nitrogen and improves the soil fertility, and can be used as fodder.

Rotate crops. Crop rotation is probably the striga control method that takes the least work. Plant crops other than cereals in the field for more than 3 seasons. Choose crops that are profitable and which produce food, such as groundnut, pigeonpea, soybean, bean, sesame and sweet potato. Legumes are good as they encourage the striga seeds to germinate then die (► *Trap crops* above), and because they improve the soil fertility.

Use improved fallows. An improved fallow is a crop rotation using a fodder legume instead of a food or cash crop. Various legumes are suitable, including sesbania, calliandra, crotalaria, desmodium, gliricidia and leucaena.

Plant a catch crop. In catch cropping, you sow a striga host crop such as sorghum or finger millet at a high density. You let it grow for several weeks until the weeds have attached to the roots. You then uproot the crop, so killing the weeds. Two seasons of catch cropping can get rid of a lot of striga seeds in the soil. Catch cropping is a good idea if striga infestation is very high. You can use the uprooted crop as livestock feed.

Controlling striga takes a community effort

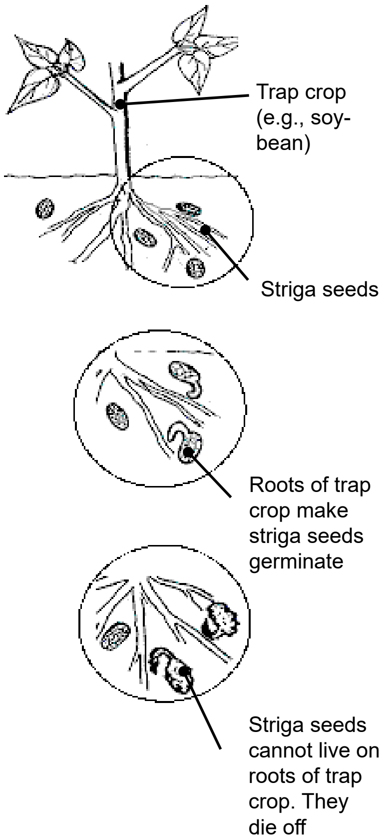

Figure 13.4. Using a false host or trap crop such as cotton or soybean can break the life cycle of striga

Figure 13.5. Hand-pulling before flowering is still the most effective way to control striga

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Figure 13.6. Uproot striga and burn it in a pit to prevent the seeds from spreading

Controlling striga does not always increase crop yields immediately

Use chemicals. Herbicides are seldom used to control striga. They are expensive and not profitable unless you are growing a high-value crop (such as a crop for seed). Regular, direct spraying of 2,4-D herbicide before flowering will help reduce the number of striga seeds in the soil.

Combine methods. Use two or more control methods together for the best chance of success. For example,

- Soil fertility improvement + crop rotation+ hand weeding.
- Soil fertility improvement + hand weeding.
- Soil fertility improvement + intercropping + hand weeding.

Experiment. Encourage farmers to experiment and learn the striga management techniques that work for them. They might test various methods on the farmer field school study plots

► *Exercise 13.3 Controlling striga.*

Remember

- Prepare the land for planting early, take care selecting seed, plant crops at the proper spacing, and weed thoroughly. This is a long-term approach.
- Weeding is an essential part of efforts to control striga. It is vital to uproot striga plants that are flowering.
- Weed the field when the first striga plants are flowering. Don't wait too long!
- Weeding must be thorough – it is not a child's job.
- Weed again once or twice each season.

Exercise 13.1 Recognizing weeds

The types of weeds that grow in the farmers' fields will determine the control method. This exercise helps farmers check the types of weeds in their fields and choose ways of controlling them.

Steps

1. Start a discussion with all the participants about weeds and weeding. Some starter questions:

- How can you take advantage of weeds? (As fodder, mulch, etc.)
- Which weeds do you have to control carefully? Those that stand up straight? That climb up the crop? That have spreading roots? That quickly grow tall? Why?
- How do the roots of weeds affect the crops? Do deep-rooting weeds have any benefits?
- Why are some weeds, such as striga, so harmful to the crop? Do some crops hinder the growth of certain weeds?

2. Divide the participants into groups of 5 people each.
3. Explain the objectives of the exercise.
4. All groups gather in the field. Then ask each group to walk across the field in a different direction.
5. Each group observes the weeds as they walk: the types and numbers of weeds, their height, etc.).
6. Bring the groups back together. Ask them to discuss and compare what they have seen.
7. Facilitate a discussion using the questions below.

Questions to stimulate discussion

- What types of weeds are there in the field? How many are there?
- What are the dominant weeds? (Record the local names.)
- Are there weeds you discovered for the first time?
- How would you classify the weeds? Which are difficult to control, and why?
- Is it worthwhile to weed the field? What are the costs and benefits?
- Do you have the same problems in your own fields?
- How do you control weeds in your fields? What do you use for weeding? Is it effective?
- What is the best time to weed? When during the cropping season do you weed?
- How could you test different ways to control the most important weeds?

Learning objectives

Decide which weeds are the most serious.

Identify factors that cause weed problems.

Identify current practices and new ways to control weeds.

Think of field exercises and experiments on weeds.

Develop ways to manage weeds.

Timing

During the cropping season, when weeds are growing.

Preparation

Choose a cropped field (or fields) where you can hold the field part of the exercise.

Duration

2 hours.

Materials

Notepaper, pens, hoes.

Exercise 13.2 Weed management trial

Learning objectives

Understand the effects of weeds on crop growth and yield.

Realize that good weed control during a crop's critical period is the most effective.

Timing

This is a season-long field study during the cropping season.

Preparation

Choose a study field with many weeds. The field should be big enough to lay out several treatment plots side by side. One plot might cover 50 m^2.

Duration

Weekly visits of 1–2 hours to the study field.

Materials

Maize or sorghum seed, hoes, measuring tape, record sheets for experiments, notepaper, pens.

Adapted from

Hughes and Venema (2005)

This exercise helps farmers test various ways to control weeds in their fields. Because it uses small plots and a joint study field, no single farmer carries the risk of crop failure. The suggested treatments can cover the timing of weeding as well as different methods farmers want to try out.

Steps

1. Explain what the group is going to learn.
2. Design treatments together with the participants. For example, if sorghum is the main crop in the area, the participants might decide to test some or all of the following:

- Treatment 1: Hand- (or hoe-) weeding at planting time and 30 days later.
- Treatment 2: Hand- (or hoe-) weeding at planting time and 60 days later.
- Treatment 3: Weeding as recommended by the extension service.
- Treatment 4: Farmers' weeding practice.
- Treatment 5: No weeding.

3. Mark the treatment plots with signs showing each treatment. Weed each plot according to the plan in Step 2.
4. Draw up a form to record the situation in the field each week. This form should show the crop growth (number of tillers, plant height, diseases) and weed types and numbers.
5. Visit the plots each week and study the crop and weeds. Use the forms to keep notes so you can review them at the end of the cropping season.
6. At harvest, record the crop yield for each plot.
7. Analyse and discuss the results.
8. Discuss good weed management, based on the results of the experiment.
9. Compare your results with findings of other farmer field schools, researchers, and the extension agency's recommendations. Discuss the differences. Discuss whether the participants want to do another experiment in the next season.

Questions to stimulate discussion

- Which is the best weeding practice? How did the farmers' practice (treatment 4) compare with no weeding (treatment 5)? Were there yield differences?
- Seeing the results of the experiment, is it worthwhile to weed?
- How does the cost (labour) compare with the benefits (higher yield)?

Exercise 13.3 Controlling striga

Striga is not like any other weed. To control it, you have to understand how it grows. Controlling striga is difficult. You will succeed only if you continue with determination for several years.

Learning objectives

Understand how striga grows and spreads.

Develop and test ways to control striga.

Timing

This study starts at planting time and takes 2 cropping seasons. It should ideally be extended over at least one more season.

Preparation

Before the cropping season begins, find a study field with medium or high striga numbers.

Duration

Monthly visits of 1–2 hours to the study field.

Materials

Record sheet, notepaper, pens, small plastic bags; clean (uncontaminated) seed of maize, cowpea or other crops; fertilizer, manure.

Visit 1: Early in the season

1. When the striga first emerges in the field, pull up a few affected maize or sorghum plants. Examine how the striga is attached to the roots.
2. Discuss how the weed sucks moisture and nutrients from the host plant. Explain that the weed also poisons the host plant.
3. Also pull up some unaffected plants in the same field. Check how much damage has been done during the first stages of striga growth (actually, most damage to the host happens while the striga is still underground).

Visit 2: 4–6 weeks later

4. Examine striga plants again, and uproot affected and unaffected maize or sorghum plants.
5. Collect some striga seed capsules. See how small and numerous the seeds are, and how easily they can be carried away by wind or water, or on farm tools, animals and clothing.
6. Discuss in plenary what you have seen.

Visit 3: Shortly after the crop harvest

7. Choose part of the striga-infested field to test control measures.
8. Discuss with the participants which control measures (or combination of measures) they want to try out. Explain the likely effects of different measures. Mention that controlling striga takes several seasons, and that improving the soil fertility is a vital part of the process.

The following steps use a combination of weeding, soil fertility improvement and intercropping as an example of control measures to test.

9. Remove all the striga and affected crop residues from the study field. Decide how to improve the soil fertility (manure, fertilizer, etc.). Decide on intercrops for the next season (e.g., maize and cowpea) and make sure clean seed for these crops will be available.

Visit 4: Beginning of next season

10. Plant and fertilize the selected crops, using clean seed, in part of the field you want to use for the experiment. Leave the rest of the field unfertilized, and crop it as usual.

Subsequent visits (once a month)

11. During the growing season, pull out all striga seedlings from the fertilized part of the field before they can flower. Add more fertilizer or manure as required. Try to avoid accidentally bringing in striga seeds from the untreated plot.

12. At harvest, compare the yields from the fertilized plot with that of the untreated plot.

Note: You may not see a big difference in yields in the first year. If possible, repeat the treatment next season, or even for a third year.

Questions to stimulate discussion

- Is there any difference in the crop growth and yields between the two plots?
- Is it worthwhile to control striga? What are the costs and benefits?
- Where do you think the striga seeds in the treated plot came from? (e.g., were they already in the soil, did they come from surrounding fields, etc?)
- Do you think the experiment should continue for another year? Why?
- Are you going to implement some of the control measures in your own field?

Module 14. Managing biodiversity

Farming is part of nature. It uses natural resources – soil, water, light, crops and livestock. Farming is affected by wild plants, insects and soil life, and it affects these things in return. What farmers do affects nature, and nature affects what farmers do.

Because farming is part of nature, farmers need to understand nature. They need to understand how farming practices affect plants, animals, water and soil, and how these things affect each other. Farmers should understand the farm as a complex **ecosystem**. They should work with nature as much as possible, rather than against it. A healthy soil and environment will lead to good crop yields and healthy, productive livestock.

This module will help you understand nature. It takes a broader look at the farm and the local area. It shows why it is important to maintain many different species of plants and animals on the farm. Those "many different species" include not just crops and livestock, but also wild plants, trees, insects, spiders and soil life. Together, they are known as **biodiversity**. All these species are part of a complicated web of life and are vital for a healthy environment and to support a productive farm.

This module draws on many of the preceding modules in this manual (► *Figure 14.1*). You should have covered at least some of these modules before starting work on this one.

Learning objectives

After studying this module, you should be able to:

Understand how the agricultural ecosystem works.

Appreciate the need to keep many different species on and around your farm.

Identify ways to improve how you manage this agricultural ecosystem in the field, on your farm, and in the community and watershed.

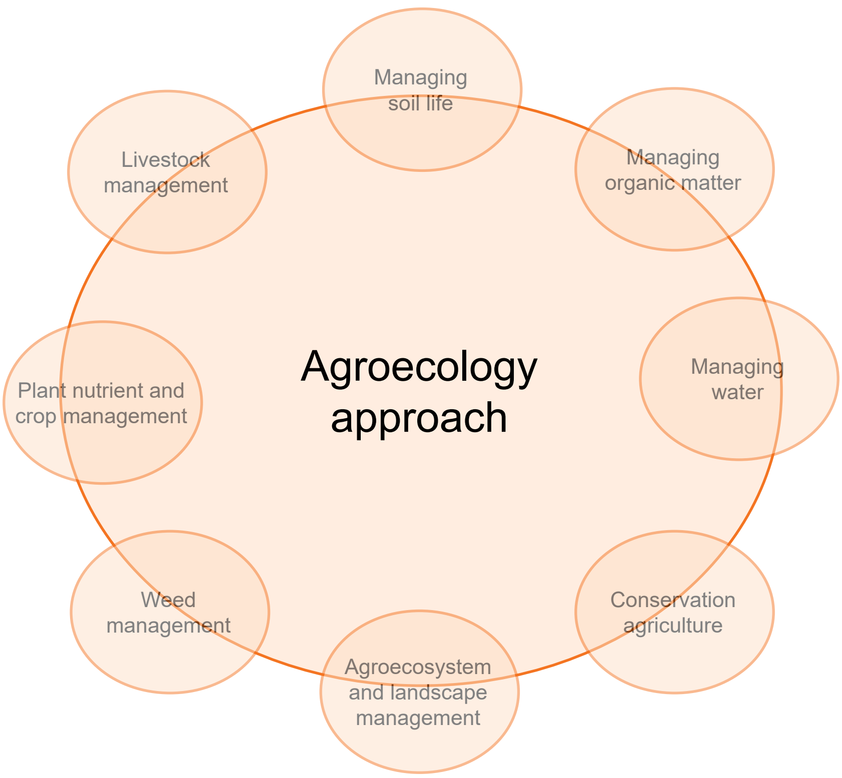

Figure 14.1. Combining the various training modules for managing the farm-household

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> **Box 14.1. Environment words**
>
> **Ecosystem.** The community of plants, animals and other living organisms, along with their environment, and the relationships between them.
>
> **Natural ecosystem.** The natural ecosystem is an area that people have not changed (or not changed much) yet. Examples are a forest, a wetland, or a natural rangeland.
>
> **Agricultural ecosystem, agro-ecosystem.** The ecosystem in a farm, along with the crops and livestock.
>
> **Biodiversity.** The range of species (of plants, animals and microorganisms) in a particular place. Places with high biodiversity (like a natural forest) have many different species. Places with low biodiversity (like a maize field) have only a few.

Changes in your environment

The environment is changing all the time. The climate may get hotter and drier, or in some places cooler and wetter. People farm the land, cut or plant trees, herd animals, cause or control erosion, and build houses, roads and dams. They dig wells, irrigate fields, use fertilizers, and spray pesticides. Farming practices change, and the number of people increases.

Understanding the past can help us understand the present. Older people who have lived in the area for many years can remember what the environment was like many years ago. They can describe how things have changed, for better or for worse. That will help you think of ways to improve the management and sustainability of the agricultural ecosystem.

► *Exercise 14.1 Changes in the farming environment.*

What is an ecosystem?

An ecosystem is a community of plants, animals and micro-organisms, along with their environment and the relationships between them.

We can understand an ecosystem by looking at the four most important processes in it:

- The energy flow driven by the sun.
- The water cycle.
- The nutrient cycle.
- The food web.

If you understand these four processes, you can use them to make farming more productive and sustainable.

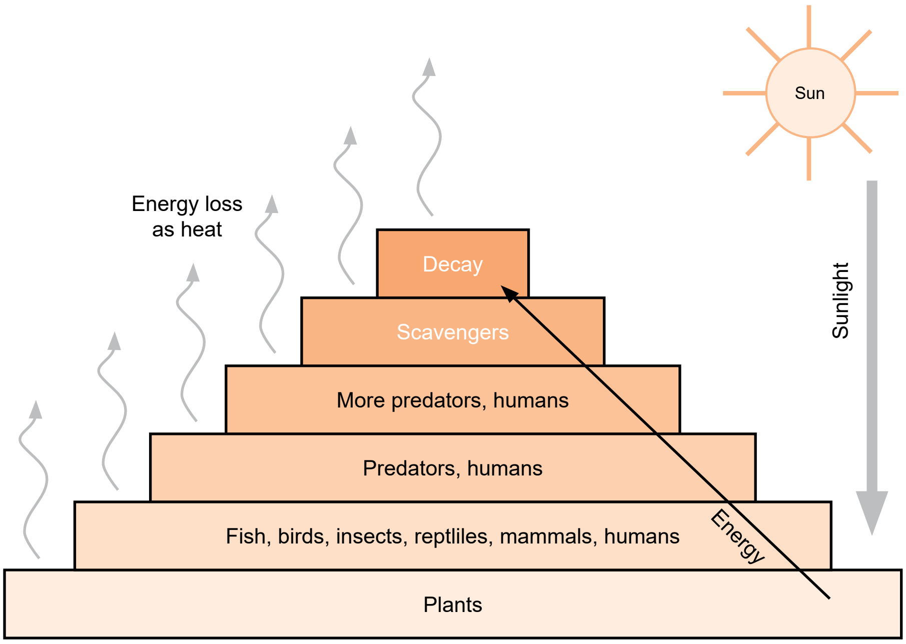


Figure 14.2. Energy flows among living things

Energy: How can you make better use of sunlight?

Plants absorb energy from the sun, and use it to grow. Animals eat plants, so taking up part of the sun's energy (► *Figure 14.2*). Some animals are eaten by predators. When we eat meat or drink milk, we in turn take some of that energy that originally came from the sun. When plants and animals die, micro-organisms decompose them.

Using sunlight

How can you make most use of the sun's energy?

- Do not leave the ground bare: grow plants all year long, or grow several different types of plants together (through agroforestry or intercropping).

► *Module 7 Managing plant nutrients* and *Module 8 Conservation agriculture* for more.

Water: How can you make better use of limited rainfall?

Water falls as rain and soaks into the ground or runs off. Plants take up some of the moisture in the soil, while the rest seeps downwards into the groundwater or percolates downhill into rivers and lakes, and eventually reaches the sea. Plants transpire water into the air, and water evaporates from the soil and from lakes, rivers and the sea. Wind carries clouds over the land, and rain falls on the ground, beginning the cycle again (► *Figure 10.3*).

Capturing water

How can you capture more rain so crops and livestock can use it?

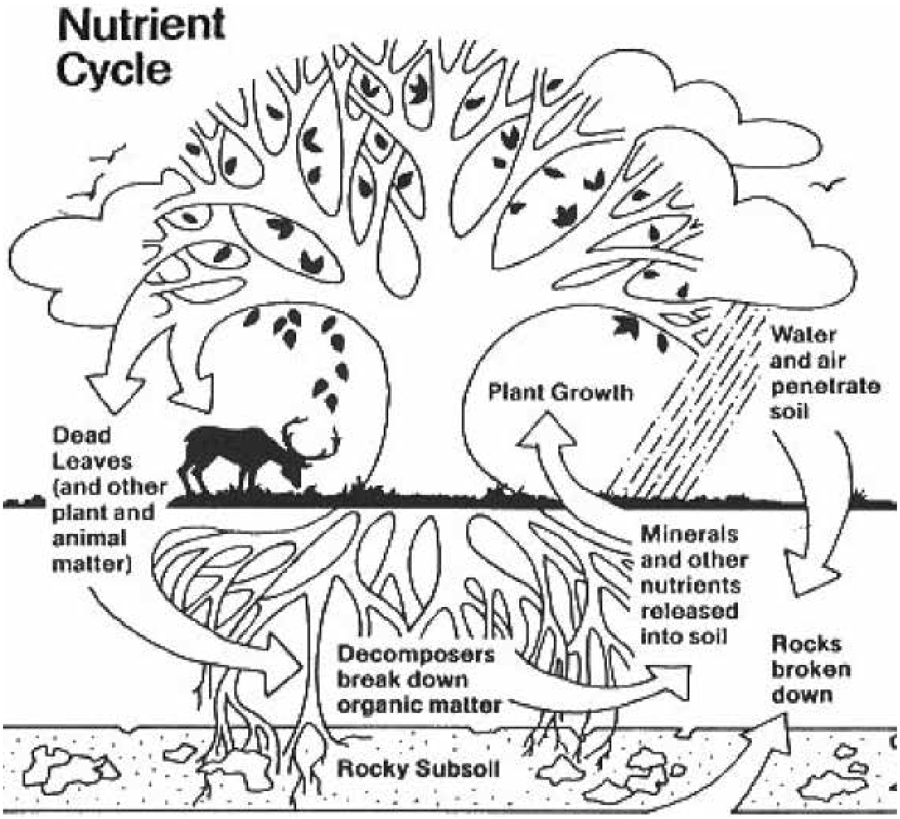
- Help water soak into the soil by covering it with mulch or planting cover crops.
- Keep water in the soil by increasing the organic matter content with crop residues, compost or manure.
- Minimize or avoid ploughing, to maintain the soil structure.
- Break up hardpans to increase the effective depth of the soil.
- Harvest water elsewhere and divert it to your fields.

► *Module 8 Conservation agriculture*, *Module 10 Managing rainwater* and *Module 11 Harvesting water for crops* for more.

Nutrients: How can you recycle nutrients on your farm?

The most important plant nutrients are nitrogen, phosphorus and potassium, though there are many others too. These nutrients are like the parts of a house: the frame, floor, cement, roof, doors, and so on. Various nutrients are essential: if any are missing, the plant or animal cannot grow properly. It is like an unfinished house.

Figure 14.3. The cycle of nutrients within the ecosystem



In a forest or other natural ecosystem, the nutrients are continually recycled. Plants take nutrients from the soil. Animals eat the plants. The animals produce manure, which goes back into the soil. When the plants or animals die, they decompose and the nutrients they contain also go back into the soil.

In farming, nutrients are lost. Farmers harvest food and take it out of the field. They burn vegetation, and the nutrients disappear as smoke. They plough the fields, and the nutrients are carried away by heavy rain.

► *Exercise 7.3 The bottle game: Nutrient movements.*

Recycling nutrients

How can you keep more nutrients on your farm?

- Leave crop residues in the field as mulch

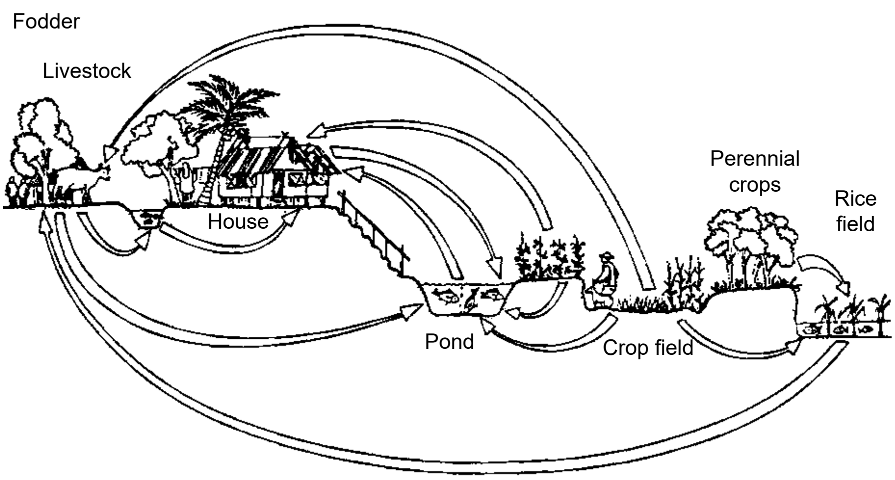


Figure 14.4. The cycle of nutrients within a farm

- Recycle organic materials – manure, human faeces and crop residues – to the field, either directly or as compost.
- Protect organic fertilizers from the sun and rain so they do not lose nutrients
- Control soil erosion, avoid ploughing, and conserve water to stop it from carrying nutrients away
- Do not burn weeds, crop stubble or other vegetation.
- Plant intercrops with roots at different depths
- Plant legumes to fix nitrogen from the air
- Plant deep-rooted trees that take up nutrients from deep in the soil

The more organic materials you can put back into the soil, the less fertilizer you will need. That saves money and is sustainable management.

The food web: How to keep the living organisms on your farm in balance?

The **food web**, or the **web of life**, is the way different types of plants, animals and micro-organisms rely on one other (► *Figure 14.5*). For example, insect-eating birds feed on plant-eating insects, which in turn feed on grass. If for some reason there is less grass, the insect-eating birds will not have

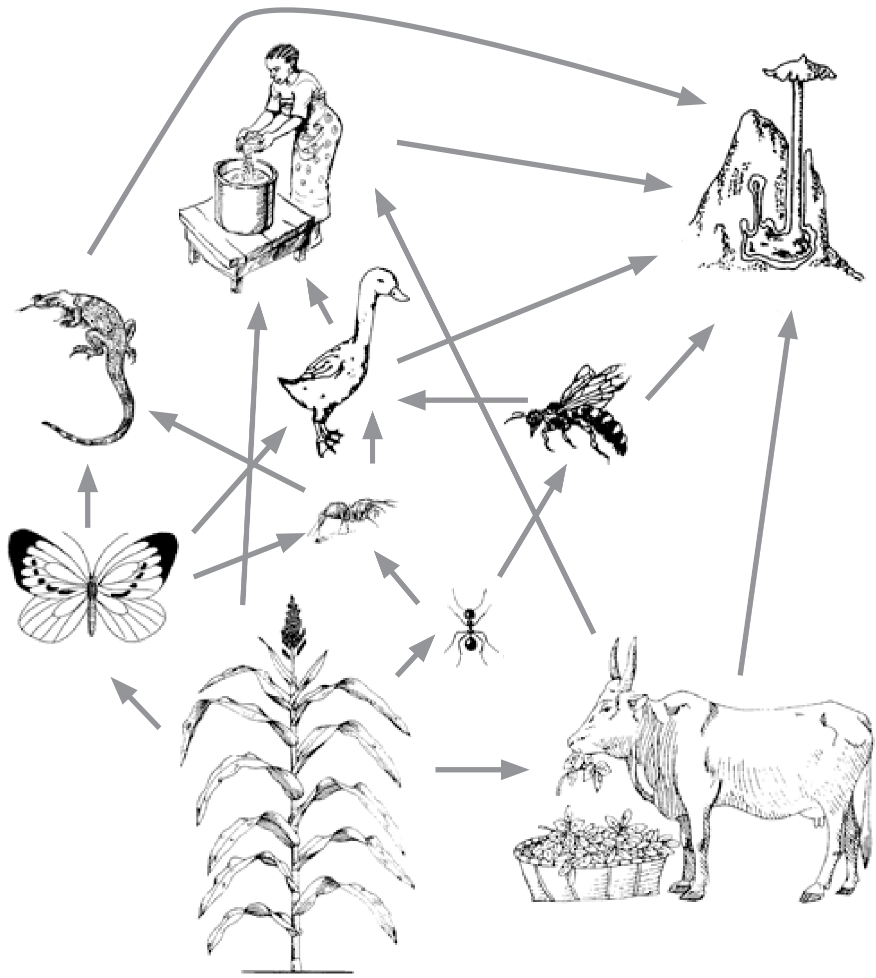


Figure 14.5. A simple food web

enough food. So their numbers will go down. The same will happen for animals that feed on the birds: jackals, hawks, owls and snakes.

An ecosystem has many different links in this food web. One type of bird may eat many different species of insects. And many other animals may also eat the same insects: other birds, bats, other insects, and spiders.

This has very practical consequences for farms. Insect-eating birds can, to some extent, control the number of pests on the crop. So do spiders and friendly insects such as dragonflies and ladybirds. If you shoot the birds and spray pesticides that kill the spiders and friendly insects, you will kill all the natural enemies of the pests. The pests multiply faster than their enemies, so you can very quickly get a big pest problem on your crop – caused by the very insecticide you have sprayed. Spraying insecticides can also kill bees and other insects that are important to pollinate crops.

A similar thing can happen if you grow just one crop (such as maize) season after season. Doing so will encourage the pests and weeds that grow well along with maize. These pests and weeds become so many that they get harder and harder to control. If you do not return organic matter to the soil, fewer living organisms can survive in the soil, and the soil becomes infertile and yields fall.

Keeping one type or breed of animal can lead to similar problems. Diseases and pests can spread quickly from one animal to another, cutting production and forcing you to spend a lot on medicines.

Overgrazing can also tip the species balance. Livestock prefer to eat certain types of plants – usually the softest, juiciest ones. They leave the tough, thorny weeds – which can take over a pasture and make it useless for grazing.

Another problem is if a new type of pest or weed arrives. None of the existing insects or other animals can eat it, so it grows and multiplies out of control. There are many examples of this:

- Water hyacinth, an aquatic weed from South America, has invaded big African lakes and rivers.
- *Chromolaena*, a fast-growing shrub from South America, causes big problems for farmers in South Africa
- *Prosopis*, a thorny tree, has invaded drylands and clogs irrigation canals in East Africa.

Sometimes these species are introduced by accident, but sometimes it is deliberate. Prosopis, for example, was introduced to Kenya to reclaim land and control erosion.

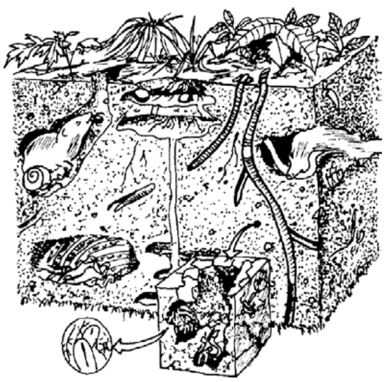


Figure 14.6. Below- and above-ground biodiversity leads to healthy agro-ecosystems

Living organisms on and around your farm

Here are some of the important living organisms on your farm:

- **Pollinators**. Bees and other insects that pollinate many crops and fruit trees.
- **Plant-eating insects.** They eat your crops and damage your harvest. But some types also eat weeds and keep them under control.
- **Animal pests.** Ticks and flies that bite your animals (and you!), and may transmit diseases.

- **Predators and parasitoids**. Dragonflies, ladybirds, spiders, some types of wasps and beetles, etc. They eat pests and keep their numbers down.
- **Earthworms**. They burrow in the ground and improve the soil structure, recycle nutrients and build up humus.
- **Other soil life.** Beetles and nematodes, fungi and bacteria – there are many different organisms living in the soil, from quite large, down to so tiny you cannot see them. They decompose organic matter, feed off each other, and help suppress diseases.

Natural ecosystems are much more diverse than farms

Some of these organisms live above the ground, but many live below the surface. But they are important even though they may be very small, or you do not normally see them.

The organisms that live below the ground depend on those that live on top of it. And plants and animals above the ground in turn depend on those below. For example, cattle eat grass. The grass uses nutrients it takes from the soil. Those nutrients come from organic matter broken down by tiny animals, bacteria and fungi in the soil. And some of the organic matter may have come from cattle manure.

Plus, the manure supports all kinds of other organisms that keep diseases in check and help keep the grass – and the cattle – healthy.

Table 14.1. Learning from nature: How to imitate a forest on your farm

	Natural ecosystem: A forest	How your farm can be like a forest
Energy ► *Modules 5, 8*	Plant leaves absorb sunlight. Animals eat the plants, and in turn eaten by predators. Micro-organisms decompose dead plants and animals.	Plant cover crops in the off-season Plant (or keep) trees and shrubs Plant relay or intercrops Plant many crops in a field
Water ► *Modules 5, 8, 10, 11*	Rain sinks quickly into the soil. Little water runs off. The soil can store a lot of water.	Keep the ground covered with crops, cover crops and mulch Apply compost or manure Minimize tillage, or avoid ploughing altogether Break up hardpans to let water sink into the soil Harvest water
Nutrients ► *Modules 5, 6, 7, 8, 9, 10, 13*	The dense roots of trees and other plants take up nutrients from the soil. The nutrients go back to the soil when leaves fall or plants die. Animals eat plants and return the nutrients to the soil as manure. Many soil organisms decompose organic material and make it available to plant roots again.	Leave crop residues in the field as mulch Return organic wastes – manure, human faeces and crop residues – to the field, either directly or as compost Protect organic fertilizers from the sun and rain Control soil erosion and conserve water Don't burn vegetation Keep the soil covered with mulch, crops or cover crops Plant intercrops (especially legumes) and deep-rooted trees
Web of life ► *Modules 5, 6, 7, 8, 9, 13*	Forests are home to many different plants and animals that all depend on each other. They use the space, light, water and nutrients efficiently. Pests and diseases do occur in natural ecosystems, but they rarely cause much damage because other organ-isms keep them in check.	Grow many different crops in intercrops and rotations Plant trees around your fields Apply manure and compost to keep the soil healthy Avoid ploughing Keep various types of livestock Plant trees and hedges to attract friendly insects Avoid spraying insecticides

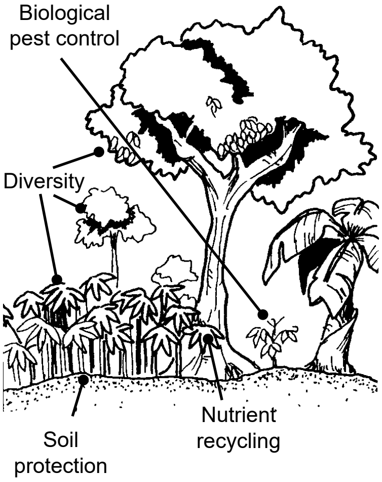


Figure 14.7. Using natural ecosystems as a model for a farm

Learning from natural ecosystems

Farms are always simpler than the natural ecosystem. Instead of the hundreds of species in a forest or wetland, there are only a few crops and livestock, plus some weeds and insects on the farm. Many farmers grow one crop on the same field, season after season. They remove hedges and cut trees, drain wetlands and plough up "wasteland". All that reduces the biodiversity and makes the farm ecosystem more unstable. It makes it easier for pests or weeds to take over a field.

Farmers can learn a lot from natural ecosystems. In fact, natural ecosystems can be a model of how to restore a degraded agricultural ecosystem.

► *Table 14.1* shows changes on the farm to resemble the natural ecosystem. Resources already available on the farm are used in a more sustainable way in order to make the farm more productive. You can present this table to farmer field school participants, then ask them to compare a forest with their own farms. Perhaps they can then suggest ways to improve their farms.

► *Exercise 14.1 Changes in the farming environment.*

► *Exercise 14.2 Comparing natural and agricultural ecosystems.*

How diverse is your farm?

We can think of two distinct types of biodiversity on a farm:

- **Living organisms that the farmer controls**: the crops and livestock.
- **Other living organisms:** soil organisms, insects, pests, weeds, trees, plants around fields and along roads, wildlife, and so on. These are indirectly controlled by the farmer and affected by what crops and animals the farmer keeps.

For example, if you plant trees around your field to produce fodder and mulch, they may attract wasps in search of nectar in the tree's flowers. These wasps may also lay their eggs in caterpillars that attack your crops. The baby wasps grow and start feeding on the caterpillar, killing it before it can damage your crop. By planting trees, you have helped control pests, even though you did not plan to do so.

How diverse is your farm? Ask yourself:

- How varied is the land use around the farm? Is the farm close to a forest? Are there hedgerows and pastures nearby? How about other patches of natural vegetation, such as wetlands and fallow land?
- How many different types of crops and animals do you produce?
- How intensively do you manage the farm? Do you allow a fallow period for your land? Or do you use the same fields year after year? Do you make compost and recycle manure? Or do you use a lot of purchased chemicals?

Maintaining a balance

How can you maintain a balance between the living organisms on your farm?

There are many ways to do this. Some are mentioned below. You can discuss these in the farmer field school, and ask participants to come up with their own examples.

- **Plant intercrops** rather than monocrops. Traditionally, in humid areas smallholder farmers often grow many different plants – both trees and annual crops – in the same field. They harvest many different crops, and the different plants form several layers that absorb all the sunlight they can. They harbour friendly insects that pollinate the plants and control pests. They protect the soil from erosion, and draw water and nutrients from different layers of the soil. In drier areas, it is not possible to grow so many crops in one field – there is not enough water. But intercrops can still be a good idea in such places, for the same reasons.
- **Plant trees.** Combining crops and trees (known as **agroforestry**) has similar benefits. The tree roots bring up water and nutrients from deep in the soil. Their leaves add to the soil's organic matter. Their branches shelter many different birds and insects that maintain a balance in the ecosystem.
- **Rotate crops**, instead of planting the same crop year after year. You can rotate cereals, legumes, fallows, cover crops and green manures. Rotating crops breaks the life cycle of pests and diseases. The roots of the various crops reach down to nutrients in different layers of the soil. Legumes fix nitrogen in the soil. ► *Module 5 Using organic materials*
- **Conserve the soil**, and apply compost and mulch. This will recycle nutrients, help the soil hold onto water, keep the soil fertile, and maintain a wide range of life in the soil. ► *Module 5 Using organic materials* and *Module 6 Encouraging soil life.*
- **Don't plough.** Zero tillage, or conservation agriculture, avoids turning the soil over. It uses rotations, mulch and cover crops to suppress pests and weeds. These protect the soil, conserve fertility and encourage soil life. ► *Module 8 Conservation agriculture.*
- **Keep livestock.** You can feed animals with crop residues, and with grass cuttings and weeds. Put the manure back on the soil to enrich its organic matter. You can set aside land for pasture, or graze animals on roadsides and field boundaries. All this helps to use resources efficiently and recycle nutrients on the farm. Keep various different livestock species, including local breeds that are well adapted to your area. But don't keep too many animals, and don't overgraze the land.
- **Encourage friendly insects.** You can encourage the natural enemies of pests is various ways. For example, do not spray insecticides; encourage insect-eating birds; and plant intercrops that shelter spiders and friendly insects. See below for some ideas on how to control pests without spraying.

► *Exercise 14.3 Biodiversity you control, and biodiversity you don't.*

Controlling pests

One of the best, long-lasting ways to control pests is to encourage spiders and friendly insects. This is called biological control.

You can do this by treating them as welcome guests. Make them feel comfortable! Give them a home and enough food, so they will always be there when you need them to deal with pests. The idea is to keep the pests under control, not to get rid of them completely.

Farms that have a lot of friendly insects:

- Have small fields, surrounded by shrubs, trees and other natural vegetation.
- Have many different crops and other plants.
- Do not use artificial agrochemicals (or use them only a little).
- Have healthy soils that are high in organic matter, with mulch or cover crops all year round.

Making your guests welcome

Here are some ways to make spiders and other friendly insects welcome on your farm:

- Don't spray insecticides or herbicides.
- Don't remove hedges or field borders. Keep fields small, and surrounded by hedges and trees where friendly insects can hide.
- Leave patches of land with natural vegetation.
- Use mulch to give the friendly insects somewhere to hide.
- Plant crops that attract friendly insects.
- Plant many different crops through intercropping, crop rotation, agroforestry, etc.
- Grow cover crops in fields and orchards.
- Plant several different varieties of the same crop.
- Plant legumes as part of crop rotations or in mixed pastures.
- Sow open-pollinated crops rather than hybrids – they are more diverse and better adapted to local conditions.
- Provide a source of water for birds and insects.

Working alone or together?

Individual farmers can apply some of the things they have learned in this module by themselves. For example, they can apply manure to their own fields, plant trees, or practise intercropping.

Other things may need several neighbours to cooperate, though. For example, controlling erosion usually means that several landowners have to work together. Managing livestock may need the whole village to agree on where and when to graze the animals. Or a farmer with many animals but little land may be willing to give (or sell) manure to other farmers.

You can ask the farmer field school participants to think about this. What things can they do alone, and what do they need to cooperate on as a group? And what would they need to convince the chief of local administration to support if it is to be successful?

Exercise 14.1 Changes in the farming environment

This exercise shows how the farm environment has changed over time. It helps farmers understand how these changes affect, and are affected by many things: the type and amount of food, access to resources, wildlife, pests and diseases, the hungry season, land and water quality, and so on.

Men and women, young and old, have different perceptions, knowledge and needs. This exercise captures these perceptions separately.

Steps

1. Organize a meeting with the community. There should be a reasonably large group of people, including young and old, men and women. Introduce the topic of changes in the environment.
2. Ask the participants to divide themselves into three or four groups, according to their age and sex: e.g., old men, old women, adult men and women, young people.
3. Ask each group to describe the farm environment as it was when they were young. Ask them to identify differences compared to today's situation. What was different then? How have things changed for the better or for worse? Each group will remember or highlight different issues. If necessary, prompt groups that have no ideas. For example, what was the situation like in terms of health, water, fuel, food crops, wild food, the hungry season, plant varieties, livestock species, etc? Ask each group to draw a picture of the landscape as it used to be. (30–40 minutes)
4. Ask each group to present its findings to the plenary. Ask them to compare the three or four landscape drawings.
5. Hold a plenary discussion about the exercise. Points to highlight:

- Which changes have occurred in crops and livestock, uncultivated plants and wildlife? What is the meaning of these changes? For example, for the frequency and severity of pests and disease outbreaks, food availability throughout the year, the time spent on certain household or farming activities, the family's health, and so forth.
- What were the effects – good and bad – of these changes on the ecosystem? For example, on the cycling of nutrients, pollination, friendly insects, etc.
- Which farming practices have been good, and which ones have been harmful? For example, burning, nutrient recycling, intercropping, mixed livestock and crop farming, rotations or monocultures, agroforestry, weed and pest control, etc.

6. Ask people which good aspects from the past they would like to reintroduce today. For example, land use, biodiversity, management practices, etc. How might they do this? Ask the participants to show their ideas on a drawing of tomorrow's landscape. Which constraints keep them from putting this into practise? How can these constraints be overcome?
7. Ask if there is anything else they would like to see in their environment in 5 or 10 years' time. How can this be done? Show these ideas also on the drawing of tomorrow's landscape.

Learning objectives

Understand how the farming environment has changed.

Understand the implications of these changes.

Timing

Best when you start to discuss farm diversity. You can revisit it later if needed when you need to review changes that have occurred over time.

Preparation

Organize the meeting, and make sure that a large and diverse group of people attend.

Duration

At least half a day.

Materials

Notepaper, pens, large sheets of paper, marker pens.

Notes

Try to keep the focus on issues of diversity and ecological functions. If the participants wander off in their discussion (for example, to talk about marketing), then bring the discussion back on track but arrange another time to analyse the other issues.

The participants may raise issues they can do little about – such as pressures on land (land sizes, shortage of grazing, etc.). But they may be able to think of ways to use resources better, or to earn money in other ways. This could also be a topic for a separate discussion.

Guide the participants to think of practical ways to improve the ecosystem, either as an individual farmer, or as the community.

The community may need further help to get the support of the local authorities or service providers. For example, you (or someone else) may be able to arrange for local people to get training, seed, credit or technical advice to put their plans into effect.

The participants should keep the drawings to refer to in the future. Draw a copy in a notebook for your own reference.

Exercise 14.2 Comparing natural and agricultural ecosystems

This exercise reveals the complexity of a natural ecosystem compared to a farm ecosystem. It helps farmers understand what biodiversity means in practice. It shows that farm ecosystems are simpler than natural ecosystems, and important things such as nutrient cycling and pest control are weaker. That makes farm ecosystems less stable. The participants can think of ways to make their own farm ecosystems stronger by making them more complex.

Steps

1. Divide the participants into two groups. One group will observe the cultivated plot; the other will look at the area of natural vegetation.
2. Ask each group to identify a 3 x 3 m square within their area. Ask them to mark the square with the sticks and string.
3. Ask each group to count and record all the different plants, animals and insects they see in the square. They should make notes about the animals and insects. Where are they – on the ground or on which type of plant? Observe what are they doing – feeding, resting, laying eggs, etc?
4. Ask each group also to look at the larger area. They should note any additional species of plants, animals and insects they see there.
5. Ask the two groups to report what they have seen, using the flipchart if necessary.
6. Ask each group to draw a web of life for their square. They should show as many interactions as possible, between the animals, insects and plants they have seen.
7. Ask the two groups to present their web of life to the plenary. Ask them to compare the two areas.
8. Ask the plenary to discuss the advantages of a diverse ecosystem compared to a simple one.

Questions to stimulate discussion

- How many different types of plants have you counted?
- How many different types of animals and insects have you counted?
- How are the webs of life in the two squares different? Why?
- What is the role of the crops in the web of life?
- What functions did you see in the natural area that you did not observe in the cultivated area? For example, pollination, earthworms and beetles digging the soil, friendly insects, organic matter, etc. What can you do to give your farm a more complex, stable ecosystem?

Learning objectives

Understand the differences between farm and natural ecosystems.

Realize that farm ecosystems are simpler than natural ecosystems.

Timing

After explaining the four ecosystem processes: energy, water, nutrients, and the web of life.

Preparation

Find a cultivated plot and an area of natural vegetation nearby. The natural vegetation could be a woodland or forest, or an area that has been fallow for many years. Both areas should be at least 25 metres square.

Duration

2–3 hours.

Materials

Notepaper, pens, large sheets of paper, marker pens, 2 pieces of string (each 12 m long), 8 sticks.

Exercise 14.3 Biodiversity you control, and biodiversity you don't

Learning objectives

Understand the different components of biodiversity on and around the farm.

Realize the practical consequences of biodiversity.

Timing

After discussing the two types of biodiversity on the farm.

Preparation

–

Duration

2–3 hours.

Materials

Notepaper, pens, large sheets of paper, marker pens.

Farmers directly manage one component of biodiversity on their farms: their crops, trees and livestock. But there is a much larger component they do not manage directly – other plants, insects, small animals, earthworms and other forms of soil life. This exercise helps participants understand these two types of biodiversity, and shows what each does.

Steps

1. Divide the participants into groups of 5 persons.
2. Ask each group to make two lists of organisms on and around the farm: those the farmer controls (crops, cover crops, trees, livestock), and other organisms he or she does not control directly (insects, earthworms, weeds, etc.).
3. Ask the groups to work out what each of the living organisms in the two lists does. For example, legumes fix nitrogen, so supply nutrients. Bees and other insects pollinate crops and fruit trees. Ladybirds feed on certain crop pests. Earthworms help decompose organic matter (so recycle nutrients) and burrow in the soil (so help the soil retain water).
4. Ask the groups to present their results to the plenary, and then invite a general discussion.

Questions to stimulate discussion

- How much control do you have over weeds or insects – species you do not manage directly?
- How could you help friendly insects do their job better? How about earthworms?
- How can you increase the biodiversity of species you manage? Of species you do not manage directly? How would changing your crops or farming practices affect the biodiversity?

Exercise 14.4 Mixed cropping versus monocropping

Fields that have many different crops tend to suffer less from pests and diseases than those with only one crop. But mixed cropping often takes more work than single crops. Farmers have to think not only of the yield and the ecosystem, but also of the cost and extra work needed if they plant mixed crops.

This exercise gets farmers to think of the advantages and disadvantages of mixed cropping and monocropping.

Learning objectives

Exchange ideas about intercropping.

Study the effects of intercropping.

Timing

Before the cropping season.

Preparation

If you plan a field test, identify a field where you can do it.

Duration

1–2 days (if field visit only) or season-long (if field study).

Materials

Large sheets of paper, marker pens.

Adapted from

FAO/CABI (2000)

Steps

1. Discuss multiple cropping with the participants. Ask in what ways multiple cropping could benefit the farmers. List the reasons on a flip chart.
2. Ask which crops are well suited for intercropping. List their characteristics. Some possibilities:

- Different plant families or species
- One crop grows fast, the other grows slowly
- One crop has shallow roots, the other has deep roots
- One tall crop to protect a shorter crop from diseases carried by insects
- A cover crop grown between the main crop rows protects the soil from rain and sun, and provides organic matter

3. Ask the participants to think of examples of multiple cropping they could compare with a common monocrop. Examples:

- **Vegetables:** Cabbage or tomato or hot pepper monocrops, compared with the same crops plus lettuce, onion or garlic.
- **Cover crops:** Maize or sorghum grown alone, compared with the same crop plus Mucuna, lablab or brachiaria grass.

4. If appropriate, help the participants design and manage a season-long field test of one or more intercrops, compared to a common monocrop in the area. Observe how the crops develop using agro-ecosystem analysis (► *Module 3 Innovation and experiments*), and measure the yields from each plot. If it is not possible to do your own field experiment, consider arranging a visit to farms in the area that practice multiple cropping.

Questions to stimulate discussion

- What are the differences in the ecosystem between the multiple cropped field and the single-cropped field?
- Which crops looked healthier?
- What about the soil and water management in each plot? Did you observe difference in the soil life and the soil structure?
- What about pests, weeds and diseases in the different plots?
- Which advantages and disadvantages can you think of for the two different cropping systems?
- Which one provides the highest income for the farmer?

Module 15. Farm management, marketing and diversification

Much of this module draws on FAO (undated)

Sarah farms 3 hectares of land in Kiambu district in Kenya. She grows maize, a mix of beans and pumpkins, has two dairy cows, and keeps some chickens around her home. She has been farming like this for as long as she can remember, but her maize yields have been declining and her income has fallen over the years. She joined a farmer field school to learn how to manage the fertility of her soil. The farmer field school has discussed and tested various ways to improve the soil and to boost maize yields, and Sarah is still wondering which would be the best for her farm. She recently heard on the radio that the demand for vegetables is rising. The announcer said that farmers who know how to produce tomatoes may be able to make good profits. Sarah is thinking about growing tomatoes instead of beans, and has suggested this in the farmer field school. The farmer field school members are now considering starting a commercial plot of tomatoes. They realize that to produce for the market they have to invest before they can start making money.

Sarah and her friends comes to you for advice. What technology should they use to improve their soil fertility? How should they think about markets, demand, profits and return on investment? This module may be useful to help them answer these questions.

Farmer field schools are often started to address a specific technical constraint – a pest, for example, or a disease, or infertile soils. But focusing just on the technical problem is not enough. Farmer field schools must also help farmers produce enough to eat, and a surplus to sell. That means looking at marketing and other issues too. Indeed, many farmer field schools help their members market their produce, get credit and purchase inputs.

Learning objectives

After studying this module, you should be able to:

Understand the principles of economic and financial efficiencies and planning in farm enterprises.

Help farmer field school members decide how to plan and manage their farms, especially in managing land and water and taking risks into account.

Use simple methods to analyse options.

Help farmer field school members respond better to markets, identify and plan economically attractive activities, control the purchase of inputs and marketing of outputs, and establish links to potential marketing channels.

Figure 15.1. Managing a farm takes many different types of skils

This module contains three parts:

1. Farm management decision making and planning.
2. Dealing with risk.
3. Income diversification and marketing.

Farm management decision making and planning

Why plan?

Because farmers can use their land, labour, capital and time in various ways. They have to choose how to use their various options, and those decisions influence the future in the short and long terms. Farmers are confronted with ever-changing technologies, prices and marketing situations (see below). If they are to reap the full benefits, they need to plan how best to use these resources. The tools in this module can help them reach some informed decisions.

The changing farming situation

Farmers have to deal with a constantly changing situation:

- **Prices.** Prices of inputs and outputs are constantly changing. They are affected by the supply (the availability of the product), demand (the interest of buyers), and the market environment (types of markets, distribution networks). Changes in the prices of products may make the farm more or less profitable.
- **Inputs and labour.** Farmers need many types of inputs – seeds, fertilizer, animals, feed, tools, and so on. But these inputs are not always available: they may be poor quality, in short supply, or too far away. Labour may be in short supply too: workers may be busy elsewhere, have HIV/AIDS or other diseases, or be caring for others who are ill. That can delay planting or weeding, or mean the family can work less land or keep fewer animals. A new job in town can make a farmer decide to neglect her farm – or may mean she can afford to pay for new seeds or a labourer to do the work.
- **Natural resources.** Rising populations, erosion, deforestation, and so on, affect the amount of land and water that farmers can use, as well as their quality. Security of tenure determines whether they are willing to invest in sustaining or restoring resources. Nutrient mining, erosion and fragmentation of land holdings all reduce farm profitability and affect the relative costs and benefits of certain technologies.
- **Technology.** Technology changes also affect farms. For example, a new variety of cassava may produces the same yield as older varieties, but may resist diseases better. That would mean spraying less fungicide, so lower costs.
- **Infrastructure.** Roads, electricity, water, telecommunications, markets and so on, can all make it easier to buy and sell, and widen the farmer's choices of what to grow and how to grow it. But they can also increase competition, forcing produce prices down and making them harder to sell.
- **Institutions and services.** Access to markets, suppliers, credit, research and extension services also affect the farm's performance. So too do farmers' organizations: a group of farmers may be able to buy inputs more cheaply and sell at a higher price than if they work alone.
- **Climate.** Increasingly erratic rainfall and other climate changes may cause crop failures and food shortages.

The decision-making process

Farmers make decisions within different time horizons:

- **Short-term.** These decisions concern the daily organization of farm operations such as sowing, weeding, fertilizing, harvesting, and storage.
- **Medium-term.** These decisions relate to the annual organization of the farm, such as preparing the cropping plan, including fodder and pasture crops, whether to buy new tools and use hired labour, whether to introduce new crop varieties and animal husbandry practices, decisions on household storage, processing and sale.
- **Long-term.** These decisions relate to the long-term nature of the farm: whether to buy or lease land, to construct buildings, to buy oxen, machinery and equipment, or to plant trees which would only yield benefits after several years.

Figure 15.2. Planning and decision making means making hard choices

Smallholders live in a risky environment. Poor and short of food, they are obliged to make most decisions with a short time-horizon in mind. That may conflict with, or undervalue, improvements in land and water management, which tend to generate their impacts in the medium- and long-terms.

The more market-oriented the farm gets, the more important is good planning. Farmers have to take decisions with certain objectives in mind. Smallholder farmers have several objectives that guide their choices. These objectives may include:

- Maximizing income and profits.
- Increasing production.
- Minimizing cash expenses.
- Avoiding debts.
- Achieving a "satisfactory" standard of living.
- Raising enough cash for school or medical fees.
- Transferring the farm to the next generation.
- Ensuring stable food supplies for the family.

Different families, and different familymembers, have different goals. Men may want to make money to buy new tools or a bicycle, or to pay school fees. But women may be more concerned about having enough food on the table, and young people may give a higher priority to leisure. Some groups may want to invest in livestock, while others may prefer housing, land or trees.

Who uses the various resources? And who controls them? Often, it is the men who make the most important long-term decisions, while women decide on day-to-day issues.

Here are some of the key decision areas for farmers:

- What to produce?
- How to produce it?
- How much to produce?
- What resources to use, and when?
- What inputs to use?
- How much and when to sell the produce?
- How much to keep for home use?
- Where and to whom to sell?

Figure 15.3. It is vital to keep careful records

Farmers need tools to simplify and improve these complicated decisions. Good, up-to-date information is essential. Group discussions in the farmer field school can identify what information is needed, and where to find it. Farmers are increasingly using radio and mobile phones to get information on prices and markets. But they may need to go specifically looking for information on such things as better seeds, new technology or new enterprises.

► *Exercise 15.1 Decision making.*

You can help the farmer field school members to identify what information they need, and you can advise them on how or where to get it.

Examples of information requirements:

- Which fertilizer is most suitable for my crop? How much should I apply? How and when?
- Where can I get the fertilizer, and how much will it cost? How can I get it cheaper?
- How much extra yield can I expect this season? Next season?
- Will the extra yield be worth more than the cost of the fertilizer?
- What are the risks? What other choices do I have?

Knowing what you've done: Farm management records

Farmers should keep records of what they have done on the farm, the costs, yields, and so on. This will help them make informed decisions. Records are useful to:

- Measure and compare the performance of various crops or types of livestock.
- Compare the performance of different farms.
- Check the farm's financial position.
- Compare alternative technologies or enterprises.
- Monitor the use of resources.

Examples of farm records

It is possible to keep records in different ways. ► *Tables 15.1* to *15.5* give examples.

You can help the farmer field school members to develop their own record formats to suit their own needs. Even people who have little or no formal education can keep records in form of farm sketches, plans or other illustrations.

A farm sketch can be used to stimulate discussion on how to improve the farm layout and resource management. For example, where should the compost heap go? How about trees for shade and fruit, or a livestock stall?

A community resource map can help local people decide where to plant a woodlot, site terraces and cutoff drains, and so on.

► *Exercise 15.2 Farm records.*

Box 15.1. Finance words

Variable costs. Costs that depend on how much you produce. The cost of things like seeds, fertilizer and labour.

Fixed costs. Costs that stay the same whether you produce a lot or a little. The cost of things like hiring land, buying a plough or building a grain store

Gross margin. A rough measure of profit: your gross income minus your variable costs.

Gross income. The money you get from selling a product.

Partial budgeting. A way of calculating the change in income if you make a change in your production. Simpler than calculating a full budget.

Break-even analysis. A way to work out whether it will be profitable to adopt a new technology or plant a new crop.

Sensitivity analysis. A way to check whether you will still make a profit if the yield (or price) is higher or lower than expected.

Table 15.1. Example of crop material input record

Enterprise: Maize Area planted: 0.4 ha Plot no. 1

Application date	Type of input	Quantity	Price per unit (KSh)	Value (KSh)
2 Mar	Fertilizer	100 kg	30	3000
15 Apr	Pesticide	0.5 litres	800	400
Total				3400

Table 15.2. Example of livestock material input record

Enterprise: Cattle Number of animals: 2

Application date	Type of input	Quantity	Price per unit (KSh)	Value (KSh)
3 Apr	Dairy meal	70 kg	10	700
8 Apr	Hay	5 bales	50	250
Total				950

Table 15.3. Example of crop production record

Date	Plot no.	Crop	Output type	Sold			Con-sumed	Given away
				Quantity	Price (KSh) per unit	Value (KSh)	Quantity	Quantity
3 Apr	1	Maize	Dry maize	5 bags	1400	7,000	4 bags	1 bag
8 May	3	Beans	Green beans	600 kg	50	30,000	10 kg	–
1 Aug	4	Banana	Bananas	20 bunches	200	4,000	5 bunches	3 bunches
Total						41,000		

Table 15.4. Example of livestock production record

Date	Animal type	Output type	Sold			Consumed	Given away
			Quantity	Price (KSh) per unit	Value (KSh)	Quantity	Quantity
1 Feb 2007	Dairy	Milk	20 litres	15	300	4 litres	1 litre
1 Feb 2007	Chicken	Eggs	24	–	–	24	–
Total					300		

Table 15.5. Example of labour record

Enterprise: Maize. Area planted: 0.4 ha Plot no. 1

Date	Farm operation	Family	Hired			Total labour days
		Person-days	Person-days	Cost per day (KSh)	Value (KSh)	
5 Mar	Land preparation	3	6	200	1200	9
30 Mar	Weeding	15	–	–	–	15
Total						24

Working out your profit: Gross margins

A gross margin is a rough guide to the amount of profit the farmer makes. It is the total amount of money a farmer makes, minus the costs the farmer incurs. You can calculate a gross margin for a particular crop or enterprise (such as a dairy or chicken-keeping operation). You can also calculate the gross margin for the farm as a whole.

Gross margins are particularly suitable for farmers who buy inputs and sell their produce. A high gross margin is good. If your gross margin is small, think about how you can make it bigger. Perhaps you can earn more by planting earlier, using a different management technique, or storing your produce until the price is higher. You might be able to find ways to cut costs. Or you may decide to switch to a different crop.

If your crop yields very poorly or fails completely, your costs will be higher than your income. In that case your gross margin will be negative.

Calculating a gross margin

1. Choose which enterprise (crop or livestock type) you want to calculate the gross margin for.
2. Calculate your total income from this enterprise. If you sell all of the output, this is the total amount of money you get. If you only sell part (and eat the rest), calculate the amount of money you would have earned if you had sold it all. You can work this out by multiplying the total yield by the farm-gate price.

Farm-gate price	x	Total yield	=	Gross income

3. Calculate the costs of running this enterprise. Include all the costs you have incurred this season to produce the crop or livestock: seed, fertilizer, hired labour, etc. (In financial jargon, these are called the **variable costs**.) Do not include **fixed costs** – things like the hire of land, the purchase of a plough or the rebuilding of a grain store. Those things may last for several seasons or are not related directly to the particular enterprise.
4. Subtract the variable costs from the total income to find the gross margin:

Gross income	–	Variable costs	=	Gross margin

Example

You grow a hectare of maize. You get a yield of 2500 kg. You keep 1500 kg for your family and sell the remaining 1000 kg for KSh 12,000.

- Farm-gate price = KSh 12/kg

How much would you have earned if you had sold your whole yield?

Farm-gate price	x	Total yield	=	Gross income
2500 kg	x	12 KSh/kg	=	KSh 30,000

Your gross income is KSh 30,000.

Now look at your costs. You spend the following on inputs:

- DAP fertilizer: KSh 5,800
- Hired labour: KSh 8,700
- Maize seed: KSh 5,300
- Total costs: KSh 19,800

Your gross margin is:

Gross income	–	Variable costs	=	Gross margin
KSh 30,000	–	KSh 19,800	=	KSh 10,200

You can calculate gross margins for different technologies or farm enterprises to see which is the most profitable. ► *Box 15.2* shows an example from a farmer field school that tested four different combinations of fertilizer for maize.

Box 15.2. Gross margins: Comparing fertilizer combinations for maize

A farmer field school in Mbeere district, Kenya, studied various fertilizer combinations for growing maize. They tested the following combinations:

Manure: 1 handful per planting hole (16 t/ha)

DAP fertilizer: 1 teaspoonful per planting hole (216 kg/ha)

Manure + DAP fertilizer

Manure + DAP fertilizer + tithonia (a plant rich in phosphorus) (3.6 t/ha)

The group kept records of the labour and other inputs, and measured the yield of the four plots. They also kept records of the costs of the various inputs. This was easy for the DAP fertilizer and seed, which they had to buy.

But putting a price on other inputs was a little more complicated. For labour, they counted the number of days needed and multiplied this by the daily wage for a labourer. For tithonia, they worked out the cost of the labour needed to collect it. For manure, they used the price the manure would have cost if they had had to buy it.

► *Table 15.6* shows their calculations of the gross margin for each plot. It shows that the combination of manure, DAP fertilizer and tithonia gave the highest gross margin. After considering other factors, such as the plant height and the number of pests and weeds, the group decided to use this combination.

Table 15.6. Gross margin for a hectare of maize

	Manure	DAP fertilizer	Manure + DAP	Manure + DAP + tithonia
Maize grain yield	2,500 kg	3,000 kg	3,700 kg	4,400 kg
				KSh
Gross income	30,700	33,700	42,700	51,400
Variable costs				
Manure	13,900	–	13,900	13,900
Tithonia	–	–	–	1,000
Labour	9,300	8,700	9,000	10,100
DAP	–	5,800	5,800	5,800
Seed	5,300	5,300	5,300	5,300
Total variable costs	**28,500**	**19,800**	**34,000**	**36,100**
Gross margin	**2,100**	**13,800**	**8,600**	**15,200**

Comparing options: Partial budgeting

Suppose you are considering hiring a pump to irrigate a field where you'd like to grow maize. Is it worth it?

You can use **partial budgeting** to work this out. You add up the extra income you would get from the pump, and then add up the extra costs. Take the costs away from the income, and you have a partial budget for the new pump.

This is simpler than calculating a gross margin, because you don't need all the figures for the two alternatives.

► *Box 15.3* gives an example of a farmer field school in Kenya that did this.

Box 15.3. Partial budgeting: Is it worth irrigating a field?

Members of the Manyatta farmer field school in Embu District, Kenya, wanted to know if it was worth hiring a field to grow maize, and a pump to irrigate it. They worked out the costs and benefits of doing so (► *Table 15.7*).

They found that they would have to invest KSh 46,000 to hire the field and pump, but that they could expect to earn KSh 57,000. That would give them a profit of KSh 10,500. A good investment, they decided.

Table 15.7. Partial budget for an irrigated maize field

	Amount (KSh)
Additional gross income	
55 bags of maize	55,000
Animal fodder	2000
Total	**57,000**
Additional costs	
Hiring pump and land	10,500
Labour	11,000
Other costs (seed, fertilizer, etc.)	25,000
Total	**46,500**
Benefit (income – costs)	**10,500**

Dealing with risk

Farmers deal with ever-changing situations. That means they have to deal with risk. What happens if the rains fail? What if the price of grain falls or the price of fertilizer goes up? How about if a family member falls ill? Farmers have to anticipate these possibilities and plan what to do if they occur.

They can do two things:

- Try to reduce the chance of the bad thing happening
- Reduce the damage if it does occur.

► *Table 15.8* shows some of the types of risk that farmers face, and how they try to limit their likelihood and impacts.

Table 15.8. Examples of how farmers reduce risk

	Type of risk	How farmers reduce risk
Crop and livestock production	Drought and flood Insufficient fodder Problems adapting new technologies to local conditions Pests and diseases	Choose low-risk activities Diversify enterprises Spread production geographically Select and diversify production practices Maintain flexibility Vary production capacity
Marketing	Fluctuating prices Unreliable buyers and sellers	Obtain market information Spread sales Contract farming Participate in NGO or government programmes Sign contracts specifying minimum prices
Financial	Interest payments Changes in interest rates Ability to generate cash	Work off the farm Keep a cash reserve Invest small amounts over time Acquire assets Limit credit Insure against losses
Institutional	Breakdown in supply of services Management problems in organization Changes in support and subsidies	Grow enough for subsistence Keep seeds of traditional varieties Diversify enterprises
Human	Old age Illness Death	Maintain social obligations Have many children Educate children so they can support parents

Working out when you start making a profit: Break-even analysis

Suppose you want to try a new technology to grow maize. For example, a new variety that will need extra fertilizer to produce well. You know how much it will cost, but you're not sure how much benefit it will bring. How much will the new variety have to yield for you to break even?

You use break-even analysis to work this out. You add up the costs of your current practice, and the costs of your new practice. You work out the difference between them. Then you work out how much extra yield you need to earn enough to cover your costs.

► *Box 15.4* shows an example of how one farmer in Embu district, Kenya, did this.

Figure 15.4. Try to predict the risks in your business. What happens to yield and prices if it does not rain?

What happens if prices change? Sensitivity analysis

What happens if the price of fertilizer rises? If you get less yield than your hoped? If the price of maize falls? Or if the price of the seed goes up?

You can use sensitivity analysis to work out what will happen to your gross margin in each of these cases. You identify the most likely or important changes that might happen, and then you calculate how these will affect your costs and income. ► *Box 15.5* shows an example of how to do this.

► *Exercise 15.3 Understanding risks.*

Box 15.4. Break-even analysis: How much extra yield do you need to cover the costs of a new technology?

Amanda normally grows 0.4 ha (1 acre) of maize each season. She wants to plant a new maize variety that will need more fertile soil. She calculates the costs of her current practice and the new variety (► *Table 15.9*).

She calculates that the new practice will cost an extra KSh 6,000. At a maize price of KSh 1,000 a bag, that means she will have to grow an extra 6 bags to break even.

Over the last 3 years, Amanda has harvested an average of 20 bags per acre, so she would need at least 26 bags to break even. She knows that researchers get 30–35 bags with the new practice, and neighbours have harvested 23–30 bags.

Amanda decides it is worth trying out the new practice this season on about half her maize area. If it works well, she will expand it to cover the whole field next year.

Table 15.9. Break-even analysis for a new maize variety

Costs	Current practice (KSh)	New practice (KSh)
Seeds	50	1,000
Manure	500	2,000
Fertilizer	–	3,500
Labour	50	100
Total	**600**	**6,600**
Extra cost (new practice – current practice)		6,000
Price of maize	KSh 1,000/bag	
Extra yield needed (KSh 6000 / KSh 1000)	6 bags	

Income diversification and marketing

Even if they can grow all their families eat, farmers still need money to buy things. They can sell surplus food, or they can raise other, higher-value crops or livestock. They can also process their produce – such as turning milk into cheese – to get a better price.

Economic diversification helps farmers:

- Earn more money and improve their livelihoods
- Reduce their risks
- Make farming more interesting for young people
- Have more money to spend on sustaining resources and managing their farms better.

Box 15.5. Sensitivity analysis: Taking changes into account

Amanda (► *Box 15.4*) is still worried. She wants to know what will happen if the price of seeds or fertilizer rises, or if the maize price falls. Will she still make money?

First, she works out the situation given the current prices (see the first four columns in *Table 15.10*). She finds that she can expect a gross margin of KSh 24,350 if the prices stay the same and she gets the yield she expects.

Amanda then works out what will happen if the price of fertilizer goes up by 20% (fifth column in the table). Her gross income stays the same (KSh 30,000). The cost of seeds, manure and labour stays the same, but the price of fertilizer goes up from KSh 3,500 to KSh 4,200 (the figure is shown in bold italics in the table). That pushes the total costs up to KSh 6,350, and Amanda's gross margin down to KSh 23,650.

Amanda also works out the consequences of a 10% fall in the price of maize (column 6). That would cut her gross income to KSh 27,000, and her gross margin to KSh 21,350.

Her last concern is what happens if the price of seed rises by half (column 7). That is less serious – it cuts her gross margin by just KSh 50, down to KSh 24,300.

Amanda realizes a drop in maize prices would be more serious than a rise in the cost of inputs. She urges the other farmer field school members to start thinking of how to market their grain to get better prices.

Table 15.10. Example of sensitivity analysis (what happens if…)

	Current prices			What happens if…		
Item	**Quantity**	**Price**	**Total**	**Fertilizer prices rise 20%**	**Maize price falls 10%**	**Seed prices rise 50%**
		KSh				
Gross income	3,000 kg	10	30,000	30,000	*27,000*	30,000
Costs						
Seed	2 kg	25	50	50	50	*100*
Manure	5,000 kg	0.4	2,000	2,000	2,000	2,000
Fertilizers	50 kg	70	3,500	*4,200*	3,500	3,500
Labour	20 hours	5	100	100	100	100
Total costs			5,650	6,350	5,650	5,700
Gross margin			24,350	23,650	21,350	24,300

> **Box 15.6. From farmer field schools to marketing groups**
>
> In Kiambu district, Kenya, several farmer field schools started out focusing on soil fertility. After 2 years, they had all identified a commercial activity they wanted to pursue. Activities included growing and selling Irish potatoes and watermelons, and milk processing. At the same time, the groups continued to experiment on soil fertility, manure management and animal fodder.
>
> In Pallisa district, Uganda, the National Agricultural Research Organization asked a farmer field school to multiply groundnut seeds. The researchers provided the seeds and the farmer field school members signed a contract stating that they had to return a certain number of bags, and could keep any surplus. The groups made a considerable income from this arrangement. One farmer said that "if we had not been organized in a group we would never have been given this opportunity".
>
> Smallholder tea producers in Kericho, Kenya, organized into groups so they could benefit from a programme run by a major manufacturer to promote a "sustainable tea" label. Group members learn how to qualify for the label, monitor the required practices, and market their tea.

Farmer field schools and economic empowerment

Farmer field schools can help their members work out what to produce, how to produce it, and how to get it to marker. Introducing farmers to profitable new ideas is a good way to encourage members to continue with other farmer field school learning activities.

Farmer field schools are often started to deal with specific technical problems. But many groups come to realize other benefits of working in a group. They gradually take up various other economic activities.

It is hard for individual smallholders to buy inputs and sell their outputs efficiently. Markets may be far away, transport is expensive and hard to arrange, and the farmers are at the mercy of traders. As part of a group, the farmers can negotiate better prices, save money on transport, and buy in bulk. They can also sell large quantities of graded output to buyers who would not be interested in purchasing small amounts of ungraded produce.

Buyers, processors or traders often prefer to deal with groups of farmers rather than with individuals. They have lower handling costs, can buy larger amounts, and can train farmers in production techniques and quality control. They may also be interested in entering contracts with an established group.

► *Exercise 15.4 Exploring market options.*

Marketing plans

If you start a new activity, you have to identify customers and competitors, think of a way to attract and keep customers, and identify and anticipate change. You should draw up a marketing plan to address these questions. A good marketing plan begins with thorough knowledge of the products you want to produce of your potential customers. Knowing who buys, and why they buy, are the first steps in understanding how best to sell.

Here's how to develop a marketing plan:

- **Gather information.** Collect information on who the buyers are, and what they want. Describe the market where you hope to sell your products, the characteristics of the buyers, the existing suppliers, what type of product they want, and so on. ► *Checklist for market surveys* below for a list of things to look for.
- **Form a picture of the market.** Most markets consist of several "segments". For example, the local market for potatoes may include street sales direct to consumers, and sales to wholesalers, fast-food restaurants and supermarkets. Each of these segments has specific requirements for the product. For example, fast-food restaurants and supermarkets may want specific amounts of potatoes of guaranteed quality, of a specific size or type, delivered on certain days. Often, different producers supply different segments. Find out as much as you can about each segment, the demand for products, and who the suppliers are.
- **Analyse market problems.** What problems are there in the market? Common problems affecting the supply of produce include inadequate supplies, poor quality, lack of awareness among producers of market needs, and lack of transport and storage services. On the demand side, buyers may not understand the problems faced by producers in delivering the product, and may place unrealistic expectations on them.
- **Identify market opportunities.** Now you understand the market better, what opportunities do you see? For example, is there a time when supplies are short? Can you produce out-of-season crops to fill this gap? Is

Table 15.11. Format of a marketing plan

Enterprise	Marketing strategies						
	When?	How much?	Where?	How?	To whom?	Farm gate price	Likely problems
Maize	April	100 bags	…				
Potatoes	May	40 bags	…				

there an unmet demand for fresh vegetables in local restaurants? Does a local factory canteen need a more reliable supply of dairy products?

- **Identify your strengths and weaknesses.** Look at your (or your farmer field school group's) strengths and weaknesses. Be realistic. Can you produce the output needed, of the right quality? Can you deliver the amounts needed on time? What would you have to do to overcome any shortcomings?
- **Design strategies and actions.** Draw up your plan of action (► *Table 15.11*). That includes a plan for producing the crops or livestock you want to sell, identifying the buyers and their needs, fixing the distribution channel, and determining the prices.

► *Exercise 15.5 Preparing a marketing plan.*

Box 15.7. Checklist for market surveys

Production and market potential

- What are the main crops grown and livestock reared at present?
- What other crops or livestock could the farmers produce and sell?
- What products do customers want? How do they use the products?
- In what form should the product be sold (fresh, processed, etc.)?
- When are crops harvested? What are the yields, the prices attained and the level of production?
- What are the advantages of these crops or livestock over others in terms of yield, quality, price, and seasonality?
- What are the main production problems?

Input supplies and financing

- What inputs are needed? Can farmers get them easily? Are they the right quality? Do farmers have money to pay for these inputs?
- Do input suppliers provide advice to farmers? How good is the advice?
- Do farmers have savings? Have they saved in the past?
- Can farmers get credit? What are the sources of credit available? What types of collateral are required? Do buyers provide credit to farmers, and on what conditions?
- How easily can farmers buy or hire equipment?

Product grading and packaging

- Is the product graded? Into what grades? What quality standards exist?
- Is the product packed? What are the type, size and cost of packing material?
- What effect do different quality standards have on the price?
- What type of packaging is required? How much does it cost?

Storage

- Is the product stored? Where, and by whom?
- How much of the product should be stored?
- What storage arrangements are needed?

Transport

- How is produce transported to the market?
- Who provides transport? How much does the transport cost?
- How long do the journeys take? How efficient is the transport?
- What form of transport should be used to get the produce to the market?
- Should the produce be transported individually, or should it be pooled?
- How frequent are shipments? What is the best day for the produce to arrive in the market?

Competition

- How competitive is the market?
- Who are the main suppliers to the market?
- What are the farmers' strengthens and weaknesses compared to competitors?

Buyers and consumers

- Who buys the product, and when? What are their characteristics?
- Who are the end consumers? What are their characteristics?
- Which buyers have the best reputation?
- What competition is there between buyers?

Marketing and sales

- How is the product marketed at present?
- Where are the main markets? Where is the product sold? How large is the market? How much can it absorb?
- What percentage of the product should the farmers be interested in producing?
- How much is sold, and on what days? In which months? What factors affect sales (weather, special festivals, day of arrival in market)?
- What potential is there to boost sales? How can the product be promoted more effectively? What are current trends in popularity?
- How much contact do farmers have with the market? Where do they get information on prices, volumes and quality requirements?

Costs and pricing

- What are the costs of growing, harvesting and transporting the product?
- What market prices do producers get? What is the average price? The maximum and minimum? What prices do other farmers get for similar produce? What causes the variation in prices?
- Do farmers have any control over the price you get for your product, or do they have to accept however much the buyer offers? How might they get a better price?
- If farmers have some control over the price, what price strategy should they follow? Should they price it cheaply (so sell more), or expensively (so sell less, but get more for each kilogram or bag)?
- What is the break-even price? What profit can farmers earn at each price?
- What are the overall costs of marketing? What percentage of the final price do farmers receive?

The farming community

- Who are the leaders of the farming community?
- Who is especially successful? Why?
- Do farmers think they need help in production, processing or marketing? What type of help?

External factors

- What external factors are likely to affect sales of the produce (economic growth, inflation, rising input prices, family income)? What are most critical?
- What legal factors are likely to affect the market?

Problems and opportunities

- What are the main problems facing producers?
- What are the main problems regarding consumption?
- What complaints do farmers have about traders and buyers? What complaints do traders and buyers have about farmers?
- What local resources or facilities are not being fully used? For example, processing or storage facilities, empty returning transport, box manufacture, local radio, telephone links to the market?

Exercise 15.1 Decision making

This exercise introduces participants to decision making in a changing environment.

Steps

1. Divide the participants into three or four groups.
2. Ask each group to draw a diagram showing changes in the prices of common inputs (fertilizer, seed, etc.) over the last 3 years.
3. Ask the groups to show how market prices of common crops have changed from month to month during the same period. They can use add lines to the first diagram, or draw new diagrams to show the price changes.
4. Ask each group to choose one of the crops or livestock species they raise. Who else (apart from the farmer) has an interest in the crop or animal? For example, suppliers of feed or seed, merchants, chemical companies, and so on.
5. Ask each group to identify who makes which decisions about what to grow, how to grow it, how to sell it, etc. Men, women, elders, children, young people, etc?
6. Ask the groups to present their findings to the plenary and then invite discussion. Guide the discussion to show how their decisions can impact the farmers positively or negatively. Ask who makes decisions, and who needs training. Highlight trends and cycles in the prices of inputs and products.

Questions to stimulate discussion

- Who makes the main farm decisions? Who could (or should) make them?
- Who actually does the farm work? Who could (or should) do them?
- Who attends the farmer field school sessions? Who could (or should) attend?
- How do prices vary from season to season? What are the long-term trends in prices?

Learning objective

Understand and appreciate the importance of decision-making in a changing environment.

Timing

Before the planting season.

Preparation

–

Duration

3–4 hours.

Materials

Notepaper, pens, large sheets of paper, marker pens.

Exercise 15.2 Farm records

Learning objectives

Understand the importance of keeping farm records.

Understand that it is easy to keep records.

Learn how to keep and use simple farm records.

Timing

Any time.

Preparation

–

Duration

2 hours for initial session, 2 hours for second session, and 1 hour per week for each participant thereafter.

Materials

Notepaper, pens, large sheets of paper, marker pens, exercise book for each participant to keep his or her own records.

This exercise helps participants discover the importance of keeping records, and guides them in what to record, and how to record it.

Steps

1. Begin by discussing questions about last season's prices and yields. For example, how much did fertilizer cost last year? How about seeds and transport? What were your yields of cassava, maize or potatoes?
2. Divide the participants into four or five groups.
3. Ask each group to choose a different crop or livestock species they raise. Ask them to identify the various inputs they use to raise and sell the crop or animal.
4. Ask the groups to write down the most important things they need to remember about their crop or animal.
5. Invite the groups to present their lists to the plenary. Allow each group to explain in detail what should be recorded, and why.
6. After the plenary, request the subgroups to visit nearby farms to check what they had omitted. What other points might it be important to keep records for?
7. Afterwards (perhaps during the next farmer field school session), ask the groups to present what they found in the farms the visited.
8. Facilitate a plenary discussion on the importance of recording farm activities. Show how to keep records of inputs, production and labour (► *Tables 15.1* to *15.5*).
9. In subsequent sessions, help individual farmers to start keeping records of their own farms.

Questions to stimulate discussion

- What did you learn from the group exercise?
- How did you help participants who cannot read and write?
- Who keeps the records in the family?
- Could young people help their parents keep and make sense of records?

Notes

Some participants may have limited education, or not be able to read and write at all. Make sure they are fully involved in this exercise. They may be able to keep records by drawing simple pictures. Encourage them to attend literacy classes.

Records may be a sensitive issue between men and women. For example, men may feel their wives should not be concerned with money matters, or may want to retain control over the money earned. You may need to work with the farmer field school on these issues.

► *Exercise 2.6 Gender and socio-economic analysis.*

Exercise 15.3 Understanding risks

This exercise helps the participants understand the risks they face in their day-to-day farming activities. It helps them think of the information they need to know to manage the risks.

Learning objectives

Understand risks and find ways of addressing them.

Work out what information is needed to overcome risks, and how to gather it.

Realize the benefits of working in groups to reduce risk.

Timing

After covering record keeping and other decision-making tools such as break-even and gross margin analysis, and after ► *Exercise 15.1 Decision making* and *Exercise 15.2 Farm records*.

Preparation

Together with the participants, visit the site of field trials or the fields of farmers who have dealt with risk.

Duration

3 hours.

Materials

Notepaper, pens, large sheets of paper, marker pens.

Steps

1. Ask the participants to choose a crop or livestock species that they raise.
2. Divide the participants into four groups. Ask each group to discuss one of the following:

- Group 1: Production.
- Group 2: Processing and storage.
- Group 3: Marketing.
- Group 4: Finance.

Each group should identify the common problems, the risks and uncertainties for its topic. Ask them to think especially of problems related to land and water management.

3. Ask each group to identify ways to overcome these problems or reduce the risks. For example, they might suggest diversifying products, getting crop insurance, signing marketing contracts, or establishing group enterprises.
4. Invite the groups to present their findings to the plenary.
5. Ask the participants what information they would need to overcome the problems. How can they collect this information? How can they record and analyse it?

Questions to stimulate discussion

- What risks and uncertainties have you faced over the last 5 years in growing, processing and marketing this crop or animal, and in the finances needed for it? Have you been affected by drought, flood, poor yields, poor livestock health, poor prices, etc?
- Which of these risks and uncertainties are related to land and water management?

Figure 15.5. Use your records as a basis for your management decisions

Exercise 15.4 Exploring market options

Learning objective

Explore options to market produce as a group.

Timing

After ► *Exercise 15.3 Understanding risks.*

Preparation

–

Duration

2 hours.

Materials

Notepaper, pens, large sheets of paper, marker pens.

Farmers who market their output as a group have many advantages over those who try to sell their produce by themselves. This exercise helps the farmer field school participants generate ideas on how they might do this. It can be the first step to forming a real marketing enterprise.

Steps

1. Plenary discussion to identify needs for market empowerment and diversification activities. Try to identify advantages and disadvantages of a group approach.
2. Divide the participants into groups. Ask each group to think of ways they could take more control over their markets. For example, they might think of buying inputs as a group, market output together, process their produce to increase its value, or find ways to earn money other than through farming.
3. Ask the groups to report their ideas to the plenary. Then ask the participants to rank the ideas.
4. For the two highest-ranked options, ask the participants to think of what they would need to do for each to work.
5. Ask the participants if they would indeed be interested in putting their ideas into practice. If so, continue with ► *Exercise 15.5*.

Figure 15.6. Check the potential markets for your products before deciding what to produce

Exercise 15.5 Preparing a marketing plan

This exercise walks participants through the process of preparing a marketing plan for the two top-priority enterprises identified in ► *Exercise 15.4 Exploring market options*.

Steps

1. Discuss the objectives of a marketing plan with all the participants.
2. Divide the participants into two groups, one for each of the two enterprises selected in ► *Exercise 15.4*.
3. Ask each group to use the checklist to identify the essential information they need to prepare a marketing plan. They should try to identify 3–4 major questions per heading in the checklist.
4. Help the groups design the outline for their marketing plan, using the example in ► *Table 15.11* as a basis. Feel free to adapt this format if necessary.
5. The groups go to collect information about the market conditions for their product. They may visit the market, suppliers, buyers, and other locations. They gather information using the market survey checklist in ► *Box 15.7*.
6. When they return, the groups work on their market plan.
7. Ask the groups to present their plan to the plenary. They should justify how they arrived at their plan.
8. Discuss the plans in plenary, and decide how to put them into action.

Learning objectives

Identify major technical and marketing problems in a particular enterprise.

Identify the major information gaps and how to gather this information.

Prepare an implementation and marketing plan for the enterprise.

Timing

After ► *Exercise 15.4 Exploring market options.*

Preparation

–

Duration

2 days spread over 2 weeks.

Materials

Notepaper, pens, large sheets of paper, marker pens, checklists (► *Box 15.7*), marketing plan format (► *Table 15.11*), transport.

Module 16. Assessing impacts, learning lessons

Farmer field school groups should regularly review their experiences and achievements. They should think about what worked well, what worked less well, and why. This will let them to think how to make better decisions and how to work better.

The word **monitoring** can scare people away. Some people think it is difficult or complicated. But in fact we do it all the time: every time a farmer checks how her crop is growing, she is monitoring it.

The group can monitor some things continuously: crop and animal health, access to water, and the amount of food families have. They can also monitor the farmer field school itself: things like the group dynamics and the learning process.

Other things need to be evaluated at specific moments in time. For example, you have to wait until harvest time before you can measure crop yields and the impact of improved practices. You have to sell the produce before you know how well a commercial enterprise has performed.

Reflecting on the group's experiences and achievements can create new insights. It allows the farmer field school group to mature and ensure that they achieve their goals.

This module guides the group on how to assess their achievements and learn from their experiences.

Learning objectives

After studying this module, you should be able to:

Assess experiences and reflect upon lessons so you can improve your farmer field school's activities in the future.

Develop and implement a simple monitoring plan to assess the farmer field school process (how decisions are made and activities conducted) and the results it has achieved.

Employ various methods to gather information.

Monitoring = *focus on what is happening*

Evaluation = *focus on what has happened*

Why monitor and evaluate?

Is your farmer field school doing the right thing? Are you going in the right direction? Could you perhaps do things better, or in a different way?

To answer these questions, you need a way to reflect on and analyse what you have done. That will let you make better decisions in the future. It is important to involve all the farmer field school members in this process through what is called **participatory monitoring and evaluation**.

Participatory monitoring and evaluation lets you, and your farmer field school group, make regular observations and reflect on your findings. It lets you correct what you are doing, to ensure you are making progress. Checking the differences between various practices (as in a field experiment) is part of this process. Participatory monitoring and evaluation not only helps the farmer field school group get good results. It also helps individual members select and adapt practices for their own needs.

Often, nobody in the group feels responsible for monitoring. So you have to have rules to make sure the monitoring gets done. You can do this by jointly developing a monitoring and evaluation plan.

Defining your goals and objectives

Your farmer field school probably has various goals and objectives. **Goals** are broad, long-term aims – such as increasing food security or improving living standards. Objectives are shorter-term and more specific – such as improving soil health, increasing bean yields, or raising goat productivity.

Decide on your overall goal

↓

Choose specific objectives to meet your goal

↓

Activities to achieve your objectives

Deciding on your goals and objectives is the first step in developing a monitoring plan. The group may already have decided on these when it was set up (► Module 1). If not, you need to decide on them soon afterwards.

First, as a group, decide what your overall goal is. This may be fairly general, and different members may have different ideas. Try to make sure that the goal is realistic and reflects everyone's opinion. You may have several goals, but don't have too many – three or four is enough.

Then decide on the group's specific objectives. Your group probably decided on these when they analysed the problems they faced and decided what topics to study in the farmer field school (► *Module 2 Improving land management*). You may have several objectives, all aiming at the same overall goal.

Here is an example.

When you identified problems to tackle, the group said their main problem was no money to buy animal medicines or breeding stock. They decided to:

- Set up a nursery to produce tree seedlings so they could plant trees for fruit and fodder and to sell seedlings to raise cash.
- Study how to improve their livestock management.
- Learn how to grow trees.

The three points above are the group's **objectives**.

Their **goals** are to improve their management practices, reduce their risk, produce more for consumption and sale, and so to increase their income.

If your farmer field school is part of a larger project, check this project's goal and strategy. Make sure that the group understands the project's strategy, so their activities contribute both to the project goal and (more importantly) meet their own specific goals. Feedback from farmer field school groups is vital to ensure the project is adjusted to serve the farmers' own needs.

► *Exercise 16.1 Visioning.*

Developing a monitoring plan

Base the monitoring plan on the strategy the group has designed to reach their goals. Be as clear as possible about what you are trying to achieve, and how to achieve it.

Consider the following points when designing the monitoring plan:

- The learning process (the discussion on what, why and how to monitor) is just as important as the product (the monitoring plan).
- All farmer field school members should participate actively in the whole process. Where appropriate, involve other project partners too.
- Keep the monitoring activities clear, brief and concise.
- Be prepared to refine and revise the plan as new information comes to light. For example, add and improve on observations if necessary. But remember also that monitoring requires continuity: you have to be able to look back and observe trends over time. So don't chop and change your indicators too often.
- Prepare the first plan as a draft, then rework it if necessary.
- Do not emphasize the plan's details at the beginning.

► *Exercise 16.2 Developing a monitoring plan.*

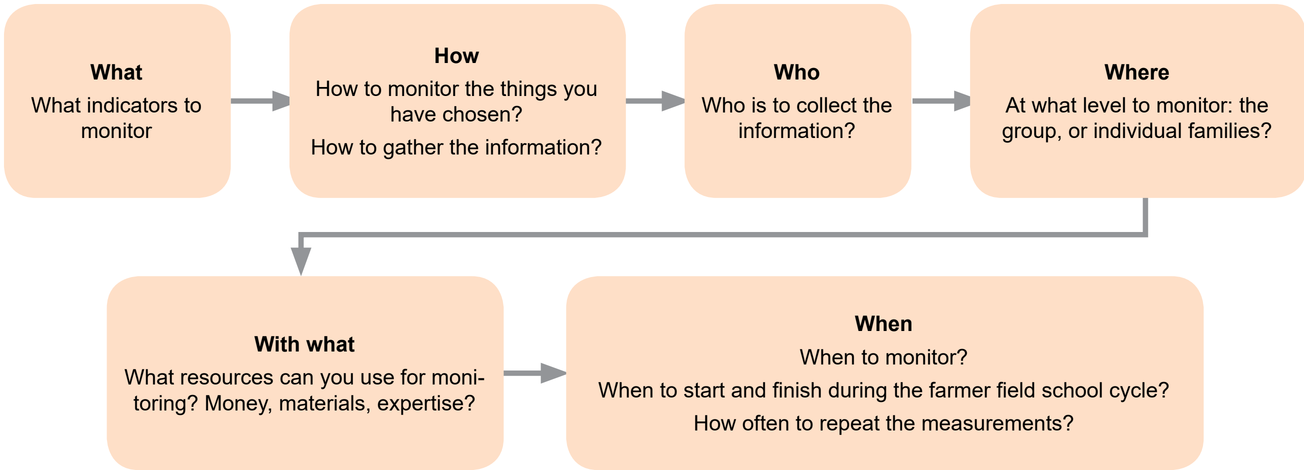


Figure 16.1. Developing a monitoring plan

Identify questions

First, identify the key questions that you need to answer so you know what progress the farmer field school is making. These questions make it easier to decide on what to monitor and evaluate. They will stop you from gathering lots of unnecessary information.

Think of questions at four levels:

- **Questions about the activity:** What you did, how you did it, what inputs were needed, etc.

Examples: How much work did the farmer field school plot need? What inputs were required?

- **Questions about the results:** What did the activity produce?

Examples: Did the plants grow well? How well did they yield? Is the soil healthier now?

- **Questions about the objectives:** How much of the produce did farmer field school members consume? Who used the money from the sale of produce?
- **Questions about the goal:** Are people better off now?

Select indicators

Once the group has drafted a list of such questions, you can choose the information needed to answer the questions. These are the indicators.

Indicators are what you measure to answer your questions. For example, if you want to measure yield, you might want to count the number of bags of maize harvested from the field. Or you could weigh the maize instead of counting bags. Both of these (the number of bags and the weight of maize) are indicators of the yield. Choose which one is most appropriate for your needs (there's no point in measuring both, as they both measure the same thing – yield).

If you are interested in measuring a crop's performance, you might also want to record things like the plant height, the number of plants affected by disease, and the number of seedlings that survive. ► *Table 16.1* has more suggestions on indicators to consider.

Box 16.1. SMART indicators

Good indicators are SMART (specific, measurable, attainable, relevant, time bound):

Specific. The indicators should be clear in what they seek to measure. Examples: the number of women in the group; the proportion of people using manure; the percentage of farmers practising water harvesting.

Measurable. They should be measurable and verifiable. It should be possible to measure or count them. Example: yield in bags per acre.

Attainable. They should not be difficult to collect. Don't ask people to count the number of earthworms per hectare, but the number in a small, easily measurable area. The information should not be sensitive or confidential, such as money or number of cattle.

Relevant. They should be linked to the farmer field school's goals, objectives, expected results and activities. Examples: farm income, food security.

Time-bound. They should relate to the correct period of time. Examples: yield measured over a season, number of months per year when the family has enough food.

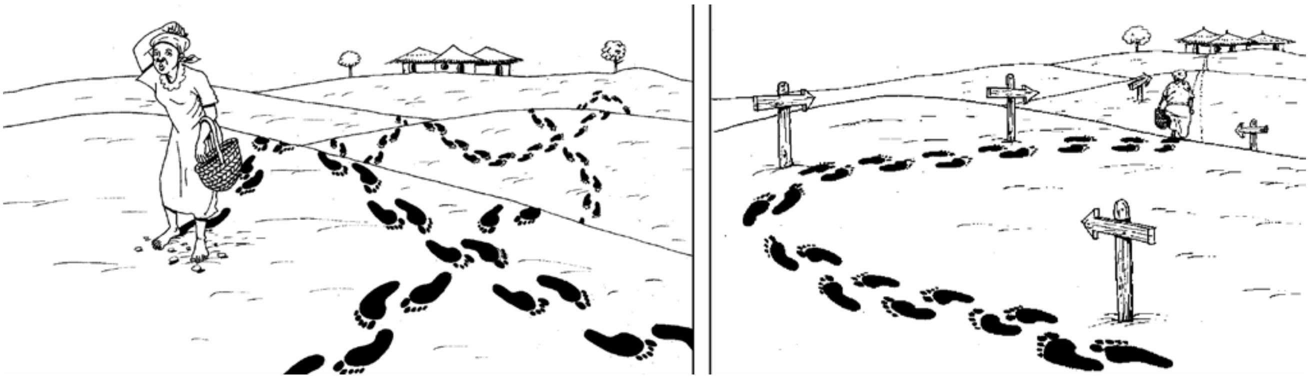


Figure 16.2. Indicators are like markers

They show you where you are, whether you are on course, what progress you have made, and how far you still have to go.

Finding suitable indicators can be difficult. Farmers often have their own ways of assessing changes they see as important. Include these in your monitoring plan if appropriate. The whole group must be involved in choosing indicators, so everybody understands exactly what to monitor and how. This may require in-depth discussions in the group.

The following questions will help you to think of possible indicators.

- If the farmer field school is heading for failure, how will you know? (Translate these failure indicators into the positive, and you will know what you want to see change.)
- What exactly do you mean when you say "improved food security" (or whatever goal, objective, or result you are discussing)?
- How do you notice when an impact has occurred? Can you give a concrete example of how to observe an impact?

Types of indicators

Indicators are often divided into process indicators and impact indicators.

Process indicators aim to measure **activities** and **inputs**. For example, how many farmers attend farmer field school sessions. High attendance is not a goal in itself for the farmer field school, but if a lot of farmers attend, it is more likely that they will reach their goal of increased knowledge. You often record process indicators in a farmer field school record book.

Impact indicators aim to measure your results, and to tell you if you are reaching your objectives and goals. For example, you might measure the

Table 16.1. Examples of process indicators (focus on farmer field school learning activities)

Questions	Indicators
Are farmers participating in learning activities?	• Attendance rate, drop-out rate • Number of farmer field school sessions held • Number of times agro-ecosystem analyses carried out
Do farmers exchange information with each other?	• Number of study tours • Number of interactions with farmer innovators • Number of field days held
Are farmer developing self-confidence and team spirit?	• Number of group dynamics per session • Confidence among members to present in front of the group • Number of poems and songs developed
How is the facilitator performing?	• Participants' satisfaction at end of each farmer field school session

Table 16.2. Examples of impact indicators

Questions	Indicators
Impacts on individual farmer field school participants	
How has the wellbeing of households changed?	• Type of housing (mud, brick, iron sheet) • Number of livestock (cows, goats, sheep) • Number of children attending school • Perception of farmers of their quality of life
Has the food security changed in the members' households?	• Number of months/year that families have enough food • Amount of stored food
Have farmers become empowered?	• Number of farmer field school members attending community meetings • Perception among farmers on their involvement in decision making
Has the profitability of farming changed among members?	• Yield per unit area (bags/ha) • Income of farm produce as percentage of total yearly income
Is conservation of land and soil resources increasing?	• Percentage of land with signs of erosion • Number of trees planted in the last year • Number of buildings where water is harvested from the roof
What level of adoption of sustainable farming practices have occurred?	• Percentage of farmers practising improved land and water practices • Land area under improved technologies
Impacts at the farmer field school level	
Has the group generated income?	• Income level from group plots • Level of group savings
To what extent has the farmer field school increased networking among farmers in the area?	• Level of networking with other farmer field school groups • Level of communal action

damage caused by pests to know if a training programme on integrated pest management has been successful.

► *Tables 16.1* and *16.2* give examples of some indicators that many farmer field schools use. You can adapt them to suit your own needs. Make sure that the group as a whole decides on the indicators to use.

Most farmer field schools do experiments, which also need to be monitored and evaluated. You need to define indicators for each experiment. You collect these indicators when you visit the experiment plot each week, during the agro-ecosystem analysis. ► *Module 3 Innovation and experiments*

You can measure impacts both on the individual members of the farmer field school, and of the group as a whole (► *Table 16.2*).

Baseline and evaluation

In order to find out what you have achieved, you need to compare the situation before the start of the farmer field school activities with the situation at the end. That needs careful planning. You need to measure the same indicators at least twice: once at the beginning, and again at the end of the farmer field school activity, and perhaps in the middle too.

The first set of measurements, at the beginning, is called the **baseline**. The measurements at the end are called the **evaluation**. You compare the two sets of measurements to see the impact the farmer field school has had.

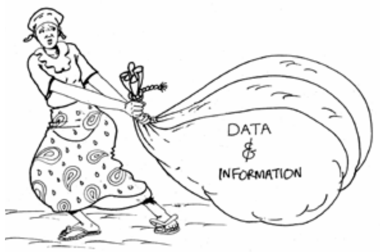


Figure 16.3. Don't collect more information than you can handle

> **Box 16.2. Example of a farmer field school record**
>
> Farmer field school name
>
> Date
>
> Farmer field school session no.
>
> Attendance: Male
> Female Total
>
> Facilitator: yes □ no □
>
> Special guests:
>
> Agro-ecosystem analysis no.:
>
> Key observations:
>
> Special topic held: yes □ no □
>
> Title of special topic
>
> Other events carried out since last farmer field school session (field days, tours, etc.).

> **Box 16.3. Types of interviews**
>
> You can hold interviews and discussions in different ways:
>
> **Informal.** No logical structure; think of questions on the spot. Example: "You talked about controlling erosion: does that work in the long term?"
>
> **Unstructured.** Try to guide the responses, as in a focus group discussion. Example: "Now, let's focus on the actual benefits of manure. What are the advantages of manure versus fertilizers?"
>
> **Semi-structured.** Based on an interview checklist or discussion guideline. Example: "Did you plant any tree crops during the last year?"
>
> **Structured.** Uses a questionnaire with questions written in advance. Example: "How many meals have you eaten a day during the last week?"

If you have no baseline, you can also compare farmer field school members with non-members after the activities are over. That will let you come to some conclusions about the impact of the farmer field school activities.

Choosing how to collect information

You can gather information in many different ways. Which method to choose depends on the type of data you want to collect, time, skills, money, etc. Some methods include:

- **Measurement**, such as the crop yield, level of soil moisture, amount of income
- **Written questions**, as in questionnaires or tests of knowledge and skills
- **Oral questions**, as in interviews or group discussions
- **Pictures**, such as photographs and drawings
- **Written information**, such as records, reports, registers and minutes.
- **Stories and analogies**, as presented through drama, theatre, and poetry.

Farmer field schools often use record books, forms to record specific indicators, written questions, interviews and participatory group exercises.

Make sure your method is reliable. That means you can compare one result with another. For example, it is better to use a tape measure to measure the height of a plant, rather than to ask people to estimate the height, as different people may guess the height differently.

Farmer field school records

Every farmer field school should have a record book to note basic information about the learning sessions and group activities. Record the information for each session on a separate page. You can use this information to evaluate changes that occur during the farmer field school cycle. For example, it can show you things like attendance patterns and cash flow.

Written questions and surveys

You can gather information about individual farmer field school members through written questions, perhaps using a questionnaire. The questions should be structured in a logical and systematic way.

Gathering the same kind of information from a lot of people is called a survey. A **baseline survey** is done before activities start to find out about the farmers or community. It may also be part of the initial problem identification, and may be done to discover entry points for the farmer field school's activities (► *Module 1 Discovery-based learning*). At the end of the field school, an **evaluation survey** may be used to gather information on the impacts.

Interviews and discussions

You can get answers to many monitoring questions by interviewing individual people or by discussing the questions with a group. Interviews are good for obtaining personal views, preferences and prejudices. A group discussion can reveal how people act and think collectively, and can probe a specific topic in detail. Questions can be structured (using questionnaires) or unstructured (open-ended questions or using a checklist) (► *Box 16.3*).

► *Exercise 16.3 Pairwise interviews.*

► *Exercise 16.6 Most significant change.*

Participatory tools and exercises

Tools that allow full participation by the whole group, even illiterate farmers, and that are entertaining and interesting to carry out by the farmers are powerful way to gather information. Many of the tools and exercises used in participatory appraisal or planning are good ways to collect information that the community can identify with. A good participatory tool should serve the purpose, be well understood, be enjoyable, facilitate visualization, provoke reflection and encourage discussion. Make sure you carry out the exercise in such a way that the participants do not feel intimidated or manipulated. You can use these tools to collect data during regular farmer field school sessions.

Some of the tools that can be used for participatory monitoring and evaluation include:

Maps and sketches. You can compare maps drawn at the start of the farmer field school with maps of the same area (field, farm, village or catchment) afterwards. They tell you what changes have taken place, and where. Maps are especially useful when working with illiterate farmers and to gather information that is important for different groups (men, women and young people).

► *Exercise 2.1 Resource mapping.*

Drama and role plays allow the group to explore a topic in a relaxed, creative way. They also enable group members to share their experiences. For monitoring purposes, you can ask participants to prepare a role play on a specific topic, and to express their opinions in the drama.

Photographs can show changes in the landscape or on individual farmers' fields. Take photos of the same spot at different times to show changes and to stimulate discussions about what caused them, if the changes are good or bad, and what decisions the farmers need to make in response.

Transect walks follow a line through the village or catchment. They let you capture information on land use patterns, resources, land degradation and opportunities. They can be extremely useful for monitoring the adoption of technologies in farmers' fields.

► *Exercise 2.2.*

You can combine them with a multiple-choice test.

► *Exercise 11.3 Review of existing water harvesting systems* or *Exercise 16.4 Multiple-choice test.*

Proportional piling means using local materials (such as bricks, seeds, stones or sticks) to represent changes in production or use of inputs before and after the farmer field school. For example, pile five bricks to show how much manure was used before the farmer field school, and then the appropriate number of bricks to show the amount used afterwards.

Smiley charts can be used to gather the group's feelings about one or more topics. Ask participants to mark whether they are happy (☺), indifferent (😐) or unhappy (☹) about things like the availability of water, the amount of erosion, or the amount of food available at different times of the year.

Matrix scoring/ranking is used to compare people's preferences for various options. The ranking can be used to discover what participants think are the most important needs and opportunities. The most common ranking exercise is "pairwise ranking".

► *Exercise 2.12.*

Evaluation wheel, or spider's web. This can be used to evaluate social and technical indicators for change. Each spoke in the wheel represents an indi-

A simple evaluation: "Are you happy ☺ indifferent 😐 or unhappy ☹?"

Figure 16.4. There are many ways to collect information

cator (identified by the group). The group decides on a score to give to each indicator. They mark each score with a dot on the appropriate spoke: the distance from the centre of the wheel depends on the score. Joining up the dots on the spokes produces a diagram that looks like a spider's web.

► *Exercise 2.11 Individual voting.*

► *Exercise 16.5.*

► *Exercise 16.6 Most significant change.*

Learning from experience

Monitoring is no use unless you (and the other people in the group) learn something from the information gathered. After you have collected the information, you need to analyse it as a group, and then reflect critically on it. Only then should you start planning future activities.

This requires an attitude of curiosity and questioning. Ask questions like these:

- What occurred?
- How was the quality?
- Why did it happen like this?
- So what does this mean for us?
- Now what will be our next step?

If you do not reflect in this way, it is difficult to evaluate the changes that have occurred. Other things, apart from the farmer field school's activities, may have affected the outcome. Make sure you think of these when you reflect on the information you have collected. Involving everyone in this observation and reflection gives everyone a sense of ownership in their activities, and strengthens the group as a whole.

You also need to decide who the information is for, and how to present it. Are the results of interest only to the farmer field school group? Or could other farmers or farmer field school groups benefit from it? How about your project supporters or partners? You might consider:

- Presenting the results in a project newsletter or local newspaper
- Turning the results into pictures and presenting them to the community
- Conducting group and wider community meetings to discuss the lessons and decide on follow-up.

Exercise 16.1 Visioning

This exercise helps people to think in terms of a long-term vision, beyond their immediate daily problems. It provides a good basis for planning as it builds on people's own dreams. Working from a vision helps to open up their minds to other ways of overcoming problems.

Steps

1. Explain to the participants that they should describe how they would like things to be in 3 years' time. Their vision should relate to their livelihoods and lives as farmers.
2. Allow the participants to think quietly for 15 minutes, and perhaps write down their dreams or make a drawing of them. Then ask them to share their thoughts in subgroups or directly to the plenary.
3. Ask the subgroups or plenary to agree on a common future based on the individual reflections. They should be as specific as possible about this vision. Ask them to define a clear timeframe for achieving it.
4. Ask the participants to identify indicators they can monitor to measure if the dreams are being realized.
5. If the participants are repeating the exercise, ask them to compare their current dreams with their previous vision. Discuss any differences and what caused them – the farmer field school's activities, or something else?

Questions to stimulate discussion

- Think of the ideal situation you want to achieve in the long run. What are its characteristics?
- Complete the sentence: "I know that my vision is achieved when I see…"
- Imagine you are giving a presentation at a community meeting in 3 years' time describing how your project has been successful. What would you present?

Learning objectives

Articulate participants' dreams and visions for the future.

Identify potential indicators to monitor and evaluate impacts.

Timing

Do this exercise as one of the first activities of the farmer field school, and repeat it every 6–12 months, or however often the participants think that changes are likely.

Preparation

–

Duration

1.5 hours.

Materials

Large sheets of paper, marker pens.

Exercise 16.2 Developing a monitoring plan

Learning objectives

Identify questions to monitor the farmer field school's activities.

Identify indicators to measure these questions.

Decide how the indicators should be monitored, who should do it, where, with what and when.

Timing

At the start of the farmer field school, when planning the farmer field school activities.

Preparation

–

Duration

6 hours, or 2 sessions of about 3 hours each.

Materials

Large sheets of paper, cards, marker pens.

A monitoring plan is important because it lets you answer the right questions and avoid wasting time and collecting information you will not use.

Steps

1. Divide the participants into groups of about 5–6 persons. Ask them to think of questions to answer if they want to know if the group and its members are making progress. Ask the groups to write the questions on cards (one on each card) and hand them to you.
2. In plenary discussion, group the questions into similar topics. Rewrite them if necessary to make them clearer. Make sure the group as a whole agrees on the questions.
3. Break the participants into new groups of about 5–6 persons. Ask the groups to identify indicators to measure the answer to each question.
4. Ask a representative from each group to present the results of their work. Put the list of questions and indicators somewhere so all can see.
5. Look at the indicators and identify the ones that are most suitable and easiest to measure – i.e., they must be SMART: specific, measurable, attainable, relevant and timely.
6. Divide the questions and indicators among the subgroups. Ask each group to discuss which tools to use to measure the indicator (how), who should be responsible, where to do the measurements, with what and when. They should write down their decisions in a table (► *Table 16.3*).
7. When the groups have filled in their monitoring plan, rotate the groups so that each group gets the plan of another group in front of them. Let the new group discuss, review and if needed revise the plan.
8. In a plenary discussion, review the results of the groups.

Questions to stimulate discussion

- Is the monitoring plan realistic? Can the farmer field school group achieve it without being overloaded?
- Does the monitoring plan have cost implications? If so, where will the necessary funds come from?
- Does the group have enough knowledge to carry out the monitoring? Or is it necessary to involve other people? If so, who?
- Does the group need training on any of the tools and methods?

Table 16.3. Form for monitoring plan

Question	What	How	Who?	Where?	With what?	When?
Key question to answer	Indicators to measure	Tools, methods for gathering information	Who is responsible for gathering and analysing information	Group or individual, location	Resources you will need	Dates, frequency
1						
2						
…						

Exercise 16.3 Pairwise interviews

This exercise gives an informal evaluation of the farmer field school's impact. In it, participants assess each others' adoption of improved practices. The exercise invites them to reflect on why farmers adopt, or do not adopt, the technologies they have learned.

First session

1. Inform the participants that they will be visiting each others' farms to conduct farm interviews. Half the group will act as hosts, and the other half will visit them.
2. Divide the participants to split into small groups. Ask each group to draw up a checklist of issues and questions to explore during the farm visits. The questions should explore the farmer field school's impact on the household and farm, and how the farmer has used knowledge gained through the farmer field school.
3. Randomly divide the participants in two groups. One group will visit the farms to conduct interviews, and the other group will host the visits. Pair each of the "interviewers" with a "host".
4. Request each pair to arrange a farm visit and interview during the coming week. Tell them that the interviewers should document the information gathered on notepaper or in a record book. The interviewers will report their findings during the next farmer field school session.

Second session

5. Ask each interviewer to summarize the finding of the farm visit interview. He or she should explain how the person interviewed has used the knowledge gained in the farmer field school. The interviewer should also highlight any constraints or opportunities the host has experienced in adopting the new practices.
6. In plenary, discuss the results of the exercise.

Questions to stimulate discussion

- Is there a trend among group members as to what practices are adopted or not?
- What factors affect whether a farmer adopts practices learned in the farmer field school?
- How did the hosts perceive the exercise? Did the interview make them think of issues they had not thought of before?
- How can the transfer of knowledge from the farmer field school to individual farmers be improved?

Learning objectives

Evaluate the impact of farmer field school on individual members' farms.

Share experiences among participants.

Identify constraints and opportunities in applying what participants have learned in the farmer field school on their own farms.

Timing

Towards the end of the farmer field school cycle, or after about a year of learning.

Preparation

–

Duration

First session: 1 hour.

Second session: 2 hours.

Materials

Large sheets of paper, marker pens, notepaper or record books, pens.

Exercise 16.4 Multiple-choice test

Learning objective

Measure participants' knowledge and skills on soil health, land productivity and on-farm water management.

Timing

If the exercise is carried out twice (at the beginning of the farmer field school, and later – perhaps after a year), you can evaluate the change in farmers' knowledge. If you do this, make the two tests the same difficulty.

Preparation

–

Duration

About 2 hours for preparation and 1 hour for conducting the exercise.

Materials

Pieces of A4-size cardboard, marker pens, thread, drawing pins, sticks, live or natural specimens.

This is an entertaining way to test farmers' knowledge.

For more ideas for an exercise like this ► *Exercise 11.3 Review of existing water harvesting systems.*

Steps

1. Prepare questions about the topics covered by the farmer field school that relate directly to a local problem. For each question, think of several possible answers: several "wrong" answers, and at least one "right" answer (there may be more than one correct answer). Where possible, phrase the questions and answers so they relate to nearby things that are easy to see – such as leaves, soil samples, or a gully. ► *Box 16.4* for some examples of questions.
2. Write the questions on separate pieces of cardboard, and mount them on posts. Then set up the question posts in the field, next to the thing they are asking about.
3. During the exercise, invite the participants to walk around the question posts and write the number of the question and their answers on a piece of paper.
4. Collect the answer sheets and mark them to find out how well the participants have done.
5. Discuss the results of the exercises in plenary, and ask for comments on what the participants have seen.

Box 16.4. Examples of questions for multiple-choice test

Question 1
What is the organic matter level of this soil?

a Low

b Medium

c High

Question 2
What impact does this management practice have on the soil? (by a newly ploughed field)

a It can create a hardpan

b It can restore organic matter

c It can improve the structure of the soil

d It can provide plant nutrients

e It can help water sink into the soil

Question 3
What effect does the mulch on this field have?

a It provides nutrients to the soil

b It increases erosion

c It prevents soil moisture from being lost

Exercise 16.5 Evaluation wheel, or spider's web

This exercise allows farmers to reflect on their knowledge gaps and display the results in a visual manner. It also lets you measure changes over time so you can adjust the training curriculum accordingly.

Learning objective

Determine the knowledge levels of farmer field school participants on particular issues.

Timing

Every 2–3 months to assess further training needs.

Preparation

–

Duration

1.5–2 hours.

Materials

Notepaper, pens, large sheets of paper, marker pens.

Steps

1. Ask the participants to brainstorm important topics related to land and water that they would like the farmer field school to provide knowledge on. Avoid going into detail, and try to focus on general concepts and issues.
2. In plenary, list the topics they have identified. Cluster the most important into 4–5 main topics.
3. Arrange these main topics in form of a wheel on a large piece of paper, with each topic as a spoke of the wheel. Write the name of each topic next to its spoke. Write a 5 at the outer end of each spoke, and a 0 in the centre of the wheel (where all the spokes meet). Make four marks at equal intervals along each of the spokes.
4. Ask each of the participants to think of how much they know about each of the topics. They should rate their knowledge on a scale of 0–5 (0 = nothing, 1 = poor, 2 = fair, 3 = average, 4 = good, 5 = very good). Ask them to write their ratings on a piece of paper (illiterate participants can use stones or beans to show their rating). They should not write their names on the papers.
5. Ask someone to add up the total scores for each topic and work out the average.
6. Mark with a dot the place on the spoke that corresponds to the average score for each topic. Then join all the dots with a line. You will end with something looking like a spider's web. The web gives a quick overview of key weaknesses and strengths. The weakest aspects are those spokes that have scores close to 0; the strongest are closest to 5.
7. Discuss and review the outcome of the exercise.

Questions to stimulate discussion

- What knowledge gaps have you identified?
- What changes should be made to the farmer field school schedule and curriculum?
- Should any special topics be held, or resource persons invited to respond to these needs?

Exercise 16.6 Most significant change

Learning objectives

Identify significant changes – positive or negative – that have occurred in the community or on participants' farms.

Share information among participants about changes resulting from the farmer field school.

Timing

Hold the initial session at the start of the farmer field school cycle. Hold subsequent sessions at agreed intervals afterwards.

Preparation

–

Duration

1 hour.

Materials

Notepaper, pens, large sheets of paper, marker pens.

Rather than looking for general trends, this exercise aims to identify the most important changes that have occurred. It is especially useful to track changes in less easily quantifiable issues such as "capacity strengthening".

Steps

1. Ask the participants to identify what types of changes they need to track. They should list issues they think are critically important – perhaps relating directly to the farmer field school's goals and objectives, or crosscutting issues, such as "equal rights for men and women". Some examples are:

- Changes in farmers' participation in income generating activities.
- Changes in the management of the farmer field school.
- Changes in how farmers apply their knowledge.

2. Decide on how often you want to discuss each of these issues. That will depend on how fast things are likely to change. Some changes may happen fast, so you should discuss them more often; other things will change more slowly, so you need discuss them only every few months.
3. Ask the group a question like, "Since last month, what has been the biggest change related to (for example) the management of the farmer field school?" or "During the last half year, what do we think was the biggest change in how we have applied our knowledge?"
4. Help the group reach agreement on the single biggest change – which may be positive or negative. The discussion should provoke a rich and detailed review of the participants' experiences, as well as debate about why one change is more significant than another.
5. Ask the group to (a) write down what happened, with sufficient detail to allow someone else to verify it if necessary, and (b) explain why they have selected that particular change rather than something else.
6. Help the group decide what they can do to overcome negative changes or prevent them from recurring. Also help them decide what to do to strengthen or spread a positive change.

Questions to stimulate discussion

- What has been the biggest positive change in the last 6 months? What has been the biggest negative change?
- What can we do about a negative change? How can we avoid it from happening again in the future?
- How can we spread a positive change? How can we make sure more such changes happen?

Glossary

This glossary contains words and abbreviations used in this book, as well as a few words you may come across when talking to experts about land and water management.

AESA. Agro-ecosystem analysis

Agricultural ecosystem, agro-ecosystem. The ecosystem in a farm, along with the crops and livestock

Agro-ecosystem analysis, AESA. Regular observation, recording and analysis of the plants, animals, soil, water, pests, diseases and other organisms in field

Ammonium nitrate. A type of fertilizer that contains nitrogen

Bacteria. Very small creatures (micro-organisms) that live in the soil, in water, and many other places

Biodiversity. The range of species (of plants, animals and micro-organisms) in a particular place. Places with high biodiversity (like a natural forest) have many different species. Places with low biodiversity (like a maize field) have only a few

Break-even analysis. A method of working out how much extra yield is needed to cover the costs of a new technology

CAN, calcium ammonium nitrate. A type of fertilizer that contains nitrogen

CBO. Community based organization

CN, calcium nitrate. A type of fertilizer that contains nitrogen

Complete fertilizer. An artificial fertilizer that contains all three major nutrients: nitrogen, phosphorus and potassium

Compound fertilizer. An artificial fertilizer that contains at least two of the major nutrients: nitrogen, phosphorus and potassium. Compound fertilizers may be "complete" or "incomplete"

DAP, di-ammonium phosphate. A type of fertilizer that contains nitrogen and potassium

Decomposition. Breaking down or rotting of organic matter

Ecosystem. The community of plants, animals and other living organisms, along with their environment, and the relationships between them

Erosion. The removal of topsoil by water or the wind

Evaporation. The loss of water into the air from lakes, rivers and puddles, or from the soil that dries out in the sun. ► Transpiration

Evapotranspiration. The combined loss of water from the ground surface and from plants. Evapotranspiration = evaporation + transpiration

FAO. Food and Agriculture Organization of the United Nations: the branch of the United Nations that deals with farming

Fertilizer grade. The amount of nutrients in a fertilizer. The grade shows how many percent of the fertilizer is nitrogen (N), phosphorus (in the form of $P2O5$) and potassium (in the form of $K2O$). 100 grams of a fertilizer labelled 15:10:5 contains 15 grams of N, 10 grams of $P2O5$ and 5 grams of $K2O$. The rest of the 100 grams (70 grams) is known as ballast

FFS. Farmer field school

Fixed costs. Expenses that do not depend on how much is produced or sold. They include things like the cost of hiring land, the price of a plough or the cost of building a grain store. ► Variable costs

Food web. A diagram showing what animals eat what plants (or other animals), as well as parasites and organisms that break down dead material

Fungi. A group of organisms that include mushrooms, moulds and yeasts. Some are too small to be seen ► Micro-organisms

Gross income. The total income from an enterprise, before deducting the costs

Gross margin. The gross income from an enterprise, minus the variable costs incurred

Hardpan. A hard, compact layer in the soil

Horizon. A layer in the soil

Humus. Dark, well-decomposed organic matter in the top layers of soil

Incomplete fertilizer. An artificial fertilizer that contains two of the three major nutrients: nitrogen, phosphorus and potassium

Infiltration. The seeping of water into the soil

Integrated pest management, IPM. A way of controlling pests using a combination of cultural practices, regular observation, mechanical controls (such as hand-picking and using traps), biological controls (such as promoting beneficial insects that eat the pests), and (only as a last resort) chemical pesticides

Integrated pest and production management, IPPM. A combination of integrated pest management with crop husbandry measures to grow crops

IPM. Integrated pest management

IPPM. Integrated pest and production management

K. Potassium

K2O. Potassium oxide: the form of potassium used to calculate the fertilizer grade

Leaching. The washing of nutrients by water down through the soil

LWM. Land and water management

MAP, mono-ammonium phosphate. A type of fertilizer that contains nitrogen and potassium

Micro-organisms. Bacteria and fungi: living things that are too small to be seen

Muriate of potash, potassium chloride. A type of fertilizer that contains potassium

N. Nitrogen

Natural ecosystem. The ecosystem in an area which people have not changed (or not changed much). Examples are a forest, a wetland, or a natural rangeland

Nematodes. Tiny, thread-like worms that live in the soil

NGO. Non-governmental organization

Nitrogen, N. An important plant nutrient. Plants need it to use sunlight and to grow

NPK. Fertilizer that contains nitrogen (N), phosphorus (P) and potassium (K)

Nutrients. Substances that plants need to grow healthily and produce seeds. The main nutrients are nitrogen, phosphorus and potassium

Organic matter. Material in the soil made from rotting animals and plants

Organisms. Living things: animals, plants, bacteria and fungi. Those too small to be seen are called micro-organisms

P. Phosphorus

P2O5. Phosphorus oxide: the form of phosphorus used to calculate the fertilizer grade

Parent material. The rocks or sediments from which the soil is formed

Partial budgeting. A method of working out whether it will be profitable to adopt a new technology or plant a new crop

Permeability. The soil's ability to let water pass through it

pH. A measure of soil acidity. A low pH (less than 7) is acidic (like vinegar). A high pH (more than 7) is alkaline (like caustic soda or agricultural lime). A pH of 7 is neutral

Phosphorus, P. An important plant nutrient. Plants need it to grow and produce flowers and fruit

Photosynthesis. The way leaves absorb sunlight and make food for the plant

Plough pan. Hardpan caused by repeated ploughing

Porosity. The amount of space or pores between the soil particles

Potassium, K. An important plant nutrient. Plants need it to stay healthy

PRA. Participatory rural appraisal

Precipitation. Water that reaches the ground from the air: rain, drizzle, dew, snow and hail

Rhizobia. A type of bacteria that live in nodules on legume roots and fix nitrogen in the soil

Rock phosphate. A type of fertilizer that contains phosphate

Rooting depth. The depth in the soil that a plant's roots can penetrate. Varies from one type of plant to another

Salinity. Saltiness

Sensitivity analysis. A way to check how profitable an enterprise will be if certain prices change

SOA, ammonium sulphate. A type of fertilizer that contains nitrogen

Soil acidity. The amount of acid in the soil

Soil horizon. A layer in a soil

Soil organisms. Living things in the soil: bacteria, fungi, ants, earthworms, beetles and other animals

Soil profile. The cross-section of the soil; a vertical cut through all the layers in the soil

Soil structure. The arrangement of particles and lumps in the soil

Soil texture. The size of particles in the soil

SSP, single superphosphate. A type of fertilizer that contains phosphate

Straight fertilizer. An artificial fertilizer that contains only one major plant nutrient (nitrogen or phosphorus or potassium)

Sulphate of potash, potassium sulphate. A type of fertilizer that contains potassium

Surface runoff. Water that does not soak into the ground but flows away downhill

TOT. Training of trainers

Transpiration. The loss of water into the air from a plant's leaves

TSP, triple superphosphate. A type of fertilizer that contains phosphate

Urea. A type of fertilizer that contains nitrogen

Variable costs. Expenses that depend on how much is produced or sold. They include things like the cost of land preparation, seed, fertilizer, hired labour, and harvesting. ► Fixed costs

Water holding ability. The ability of the soil to hold onto water

Waterlogging. The filling up of pore spaces in the soil with water, leaving no space for air

For explanations of more technical terms, ► FAO's glossaries on integrated nutrient management www.fao.org/landandwater/agll/ipns/index_en.jsp and land and water terms www.fao.org/landandwater/glossary/lwglos.jsp

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Benjamin holds a BSc in animal production from Egerton University, a diploma in farm management from Egerton University, and a diploma in credit and marketing from Israel. Currently he is pursuing an MSc in management of agro-ecological knowledge and social change at Wageningen University. He has facilitated farmer field school training-of-trainer courses in Kenya for the Kenya Agricultural Research Institute's soil and legume network, the Rockefeller Foundation, the International Livestock Research Institute, and Plan International. He has organized and trained for FAO/UNDP in marketing for farmer field schools, and organized an international workshop on coconuts.

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Paul is a land management consultant in an FAO project on conservation agriculture using the farmer field school approach in Uganda. He holds an MSc in soil science and a BSc in agriculture from Makerere University, and has experience in participatory research and extension methodologies. He was formerly a research associate with the Tropical Soil Biology and Fertility Programme at the International Center for Tropical Agriculture.

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John Peter Opio is a consultant in an FAO project on conservation agriculture and land management using the farmer field school approach in Uganda. He holds a BSc in agriculture from Makerere University, and a diploma in project planning and management from Uganda Management Institute. He is currently studying for an MSc in soil science at Makerere University. He worked as a field officer EU-LEINUTS nutrition monitoring project with Makerere University, and with communities in field extension for the Ugandan Ministry of Agriculture. He has also collaborated with NGOs such as Plan International, Caritas-Uganda, the Cotton Development Organization, Sasakawa Global 2000, and Africa 2000 Network. He has 9 years' experience in conventional and participatory extension approaches.

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Helen has many years of experience in editing and producing science and technical publications. Now working freelance, she has served as head of publications in the International Centre for Research on Agroforestry, as a World Bank adviser to the national agricultural research institute in Ethiopia, project adviser for the International Development Research Centre, publications production manager at the United Nations Environment Programme, and editor and trainer in the former East African Community.

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Robina holds a PhD degree and 12 years of professional experience in irrigation and water engineering. She has worked on the wide range of research and development projects on diverse issues, including integrated water resources management, irrigation modernization, crop water productivity, capacity building, participatory irrigation management, performance of irrigation systems, gender in irrigation, conjunctive use of ground and surface water.

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