

A STUDY GUIDE for Farmer Field Schools and  
Community-based Study Groups

# **SOIL AND WATER CONSERVATION**

## **With a Focus on Water Harvesting and Soil Moisture Retention**



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## With a Focus on Water Harvesting and Soil Moisture Retention

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<sup>1</sup> Version 1.1 is currently subject to internal review by FAO. A reviewed version 2.0 will be published in due time.

## FOREWORD

In Sub-Saharan Africa, majority of the population derives its livelihood from agriculture. Smallholder agriculture accounts for 75% of agricultural production of which the majority constitutes of rainfed farming. Drought is Africa's principal form of natural disaster which often it affects rainfed agriculture dramatically. The impact of population growth in rural areas is pushing communities into unsustainable farming practices such as burning and razing of tropical forests in order to plant crops, planting in steep slopes, moving into fragile marginal eco-system, over cropping and over grazing – and subsequent depletion – of fragile arable land and over-utilization of ground water resources. It has been estimated that a sixth of the world's land area, nearly 2 billion hectares, is now degraded as a result of overgrazing and poor farming practices. Water resources for agricultural purposes are getting scarce, and there are hardly any land reserves to be brought into production to widen the agricultural base. By 2025, close to three billion people in 48 countries will be affected by critical water shortage for all or part of the year.

Growth rate of at least 6.5-7 percent per year are necessary if typical Eastern and Southern African countries are to reduce poverty at an acceptable rate and the agricultural sector is often expected to pave the way for this broad based economic growth. According to FAO, world food production will have to double in order to provide food security for 7.8 billion people expected by 2035. Productivity increase at all levels is crucial to achieve this target. In addition to improving soil fertility, water harvesting, enhancing the soil-water retention capacity and reducing soil erosion are measures that could significantly improve agricultural productivity in rainfed marginal environments. Thus, soil and water conservation practices are becoming increasingly important in the arid and semi-arid farming systems of the region.

Appropriate and site specific technologies are needed to address poverty and food insecurity. Both available scientific knowledge and indigenous knowledge by communities should effectively contribute to this process and farmers should actively participate in the design, implementation, and evaluation as well as in the dissemination of such technologies.

Farmer Field Schools (FFSs), a non-formal adult education approach is emerging as an alternative to the 'Training and Visit' system of technology dissemination. In addition FFSs effectively contribute to capacity building and empowerment of the farming community. This study guide embraces the FFS concepts and applications in addressing soil and water management issues; and effectively captures the experiences of farmers in Kenya and elsewhere. It further, offers an opportunity for farmers to experiment and learn in their own environment.

The primary target groups for this study guide are extension staff and participating farmers in the FFSs. Other farmer groups and non-governmental organisations working with farmers to address soil and water conservation related issues could also use the materials. The study guide can effectively contribute to emerging participatory research and extension approaches, while addressing one of the critical constraints in the smallholder production systems in the region; limited water resources. We also request the users of this guide to provide feedback to the authors so that the material can be revised and updated.

We would like to congratulate the authors for their efforts and the Swedish International Development Co-operation Agency (Sida) for their financial support in making this guide a reality.

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## PREFACE

A large proportion of the population in Sub-Saharan Africa earn their livelihoods from rainfed agriculture and thereby depend directly on rainfall and agricultural productivity for their survival. Poor yields in combination with a large population growth has often led to food shortages and in order to improve rural livelihood there is a big need for improved farming practices among small-holder farmers.

Climatic conditions of the semi-arid regions put high demands on farm water management. Water is the most limiting factor for agricultural production and low annual rainfall is often stated as a major reason for food insecurity. Increasing water availability for crops can be done by irrigation. However, due to lack of available water resources this is often not an option in the African drylands. A more feasible option is to utilise the limited amount of rainfall with higher efficiency. By increasing soil water content, supply and retention, crop yields can be improved significantly, and successful crop production can be made possible even in areas that are producing poorly under existing conditions. In dry regions without sources of water for irrigation and where rainfall is insufficient to cover the water demands of crops, water can be harvested in order to increase available water resources. Water harvesting and soil moisture retention are cheap and simple options for increasing soil moisture, and have successfully been used in dryland farming situation around the world.

Improved farm practices have to suit local ecological and socio-economic conditions. Soil and water management practices are highly site specific and technologies that are a success in one area might not prove useful in a different context. Therefore it is important that farm practices are developed and adapted locally, by farmers. The role of farmers in research and extension of agricultural practices needs to be strengthened so that appropriate technologies can be developed and disseminated. Resource poor farmers learn best from other farmers and prefer trying out technologies on a small scale first before adopting it on a larger area. Farmer Field Schools is an approach for farmer-led research and extension, where groups of farmers learn and experiment together.

This study guide is intended to assist farmers in learning and experimenting on improved soil and water management. The target groups for the study guide are, Farmer Field Schools, village farmer groups and agricultural extension staff. The study guide includes 7 chapters. **Chapter one** explains how to use this study guide for farmer training and on-farm technology development. **Chapter two** focuses on how to set up and run a Farmer Field School. **Chapter three** gives an overview of water harvesting and soil moisture retention approaches. **Chapter four** is intended as the actual learning material of the study guide; explaining the basic science of soil and water and giving examples of hands-on experiments that can be carried out among farmer groups. **Chapter five** gives guidelines for how to set up on-farm trials. **Chapter six** focuses on how to monitor and evaluate on-farm trials. Finally, in **chapter seven** some examples of season long farm trials are given.

The content of this study guide, and experiments included are to a large extent based on experiences from the FARMESA<sup>2</sup> (Farm Level Applied Research Methods for Eastern and Southern Africa) - funded Farmer Field Schools in Mbeere, Kenya. Some of the experiments are drawn from experiences of Farmer field Schools outside Kenya, mainly under the FARM programme in Asia. The study guide should be considered a draft

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<sup>2</sup> The Farm Level Applied Research Methods Programme for East and Southern Africa (GCP/RAF/334/SWE; FARMESA) is a regional programme funded by the Swedish International Development Co-operation Agency (SIDA) and executed by Food and Agriculture Organisation of the United Nations (FAO).

publication that will be tested on larger scale under the FAO country program in Kenya. Based on the experiences, feed back and lessons learned the study guide will be revised and a second edition published in 2002. Thus, the users are requested to provide feed back to facilitate this proposed revision. Finally, I would like to express my thanks to Mbeere farmer Field School groups, whom are the base for the development of this studyguide. I would also like to thank, Daniel Nyagaka, Benjamin Mweri, Mwamzali Shiribwa and Dr. Pascal Kaumbutho for valuable contributions to this publication.

DEBORAH DUVESKOG  
Nairobi, August 2001

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# 1. HOW TO USE THIS STUDY GUIDE

*“This book is only a small clearing at the edge of the woods where students might observe a few of the trees as they prepare to set out independently to explore the great forest which yet lies beyond”*

This manual will not provide you with solutions to your problems, but will provide you with tools and skills that can help you improve your own farming situation. Through simple experiments you will learn the basic science of soil and water management. You will also be facilitated to identify constraints and problems in your production system and learn how to identify possible solutions. From there you will learn how to test these possible solutions in on-farm trials. This will assist you to develop improved farming technologies that are suitable for local conditions and improve your production.

This manual is written for small scale farmers and extension workers that together want to improve their crop production by learning more about how to manage on-farm soil and water resources more efficient. The manual can either be used by farmer groups in structured learning setting such as Farmer Field Schools or by informal self-study groups. These groups can either be facilitated by a farmer from the group or by a specialist, such as an agricultural extension worker.

No or little formal education is necessary to follow the information given in the study guide. The text is written in a simple language for everybody to understand.

The main parts of the study guide covers:

- Learning the basic science of soil and water management.
- Identify farming problems and constraints.
- Setting up on farm trials with the aim of developing appropriate technologies to address the identified problems.
- Monitoring and evaluating on farm trials.

The contents of the study guide can be used in the order it appear, or parts and sections can be used according to specific needs and preferences of the group.

## 2. THE FARMER FIELD SCHOOL APPROACH

The Farmer Field School is described as a “School without walls”. It is a participatory method for technology development and dissemination, which gives the farmer an opportunity to make informed decisions about farming practices through discovery based learning. The field school usually involves 25-30 farmers in a given locality facilitated to find solutions to their problems. The main objective of an FFS is to bring farmers together in a learning situation to undergo a participatory and practical season-long training on a particular topic. The focus is on field observations, hands-on activities and season-long research. The FFS process also provides a learning environment that help build the capacity and leadership skills of the group. The field school deals not only with agricultural practices but also addresses other related livelihood issues. The field schools are conducted for the purpose of helping farmers to master and apply specific field management skills. The emphasis is on empowering farmers to implement their own decisions in their own fields. Within this form of training problems are seen as challenges, not constraints and participants learn to identify and tackle any problem they might encounter in the field.

The main characteristics of the FFS approach are as follows<sup>1</sup>:

- **Farmers as experts.** Farmers “learn by doing” i.e. they carry out, for themselves, the various activities related to the particular enterprise they want to study and learn about. This could be related to annual crops, soils or livestock production. Farmers conduct their own comparative studies of different treatments, in so doing they become experts on the particular practice they are investigating.
- **The field is the classroom.** All learning is based in the field. The zero-grazing unit, crop field, soil conservation sites is where the farmers learn. In sub-groups they collect data in the field, analyse it and make decisions based on the analysed data. The sub-groups present their decisions to the other farmers for discussion, suggestions, questioning and refinement before action or implementation.
- **Regular group meetings.** Farmers meet at agreed regular intervals. The frequency of meetings is determined by the enterprises farmers chose to study and the activities in the enterprise cycle. For annual crops meetings may be weekly or bi-weekly through out the cropping season.
- **Training follows the seasonal cycle.** Training is related to the seasonal cycle of the practice being investigated. For annual crop this would extend from land preparation to harvesting, for livestock from calf to calf, for poultry from chicken to chicken. For tree crops and conservation measures such as hedgerows and grass strips, training would need to continue over several years to see the full range of costs and benefits.

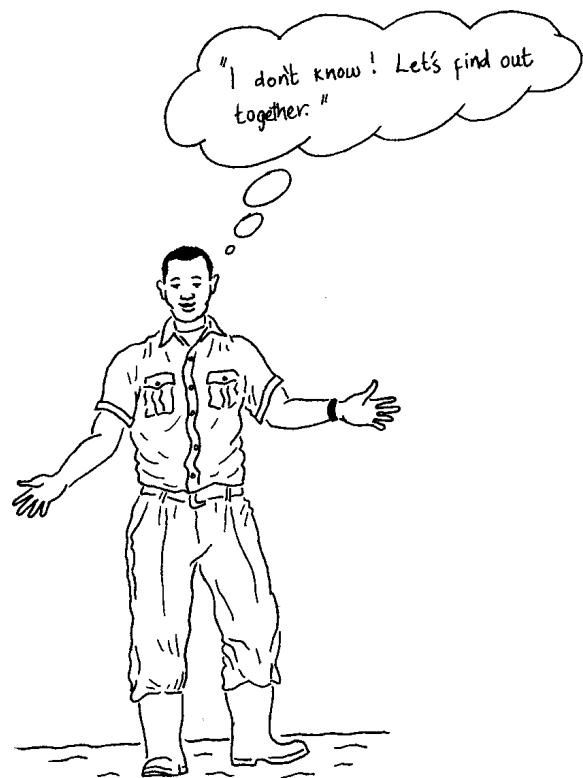
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<sup>1</sup> Adapted from: IPM Farmer Training: The Indonesian Case. 1993. FAO-IPM Secretariat, Yogyakarta, Indonesia.

- **Farmers generate their own learning material.** Farmers generate their own learning materials, drawings and posters, based on observations in the field and on experiments and field trials. These materials are always consistent with local conditions, and learners know the meaning of them, since they created the materials. Even illiterate farmers can prepare simple diagrams to illustrate the points they want to make.
- **Facilitation, not teaching.** The farmer groups are facilitated to learn, and not taught by conventional teaching methods. The role of the extension worker or scientist is to be a facilitator, rather than a teacher. Instead of lecturing farmers the facilitator will offer help and guidance to the group and serve as a source of new ideas and/or information on locally unknown technologies.
- **Group capacity building.** Through the training farmers acquire skills on communication, problem solving and discussion methods. Successful activities at the community level require that farmers can apply effective leadership skills and have the ability to communicate their findings to others.

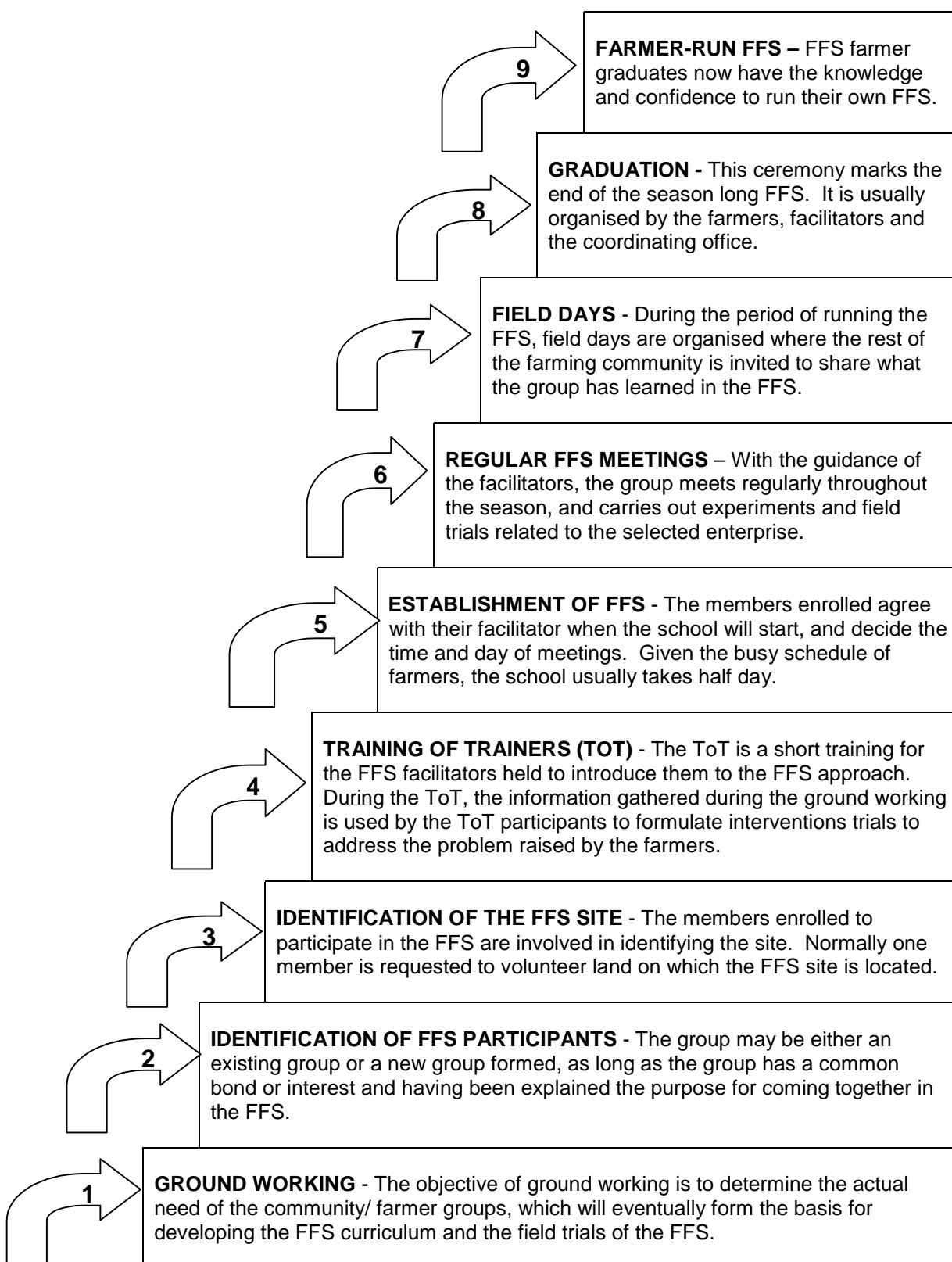


**FARMERS ATTITUDE**



**FACILITATORS ATTITUDE**

The following figure summarises the nine steps “classical” involved in setting up and running a Farmer Field School.



Prepared by Benjamin Mweri

### **3. OVERVIEW OF WATER HARVESTING AND SOIL MOISTURE RETENTION APPROACHES**

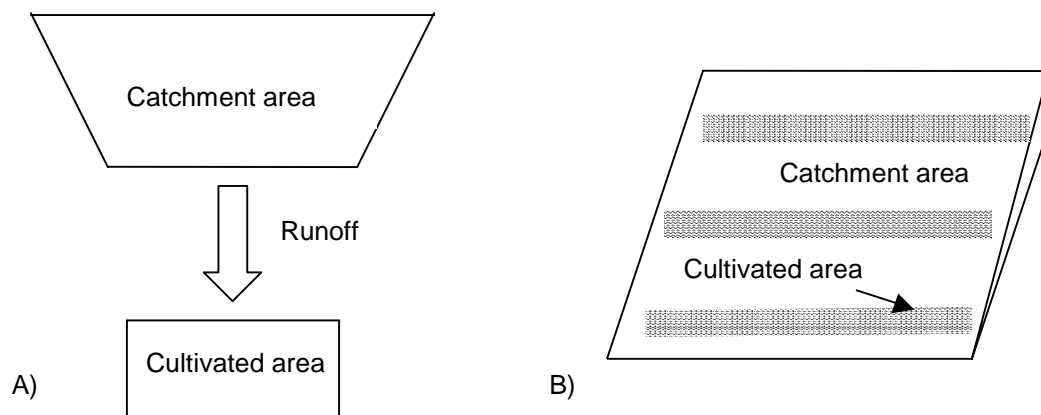
In Africa most of the food is produced by rainfed agriculture and the populations thereby depend directly on rainfall and agricultural productivity for their survival. Water is the most limiting factor for agricultural production in these regions and the low annual rainfall is often a major reason for food insecurity. Poor yields together with a large population growth have often led to severe food shortages. To improve rural livelihood there is a big need for improved farming methods and increased yields.

Climate conditions in the semi-arids put high demands on farm water management. The risk for crop failure due to droughts and dry spells is increased by erratic and high intensity rainfall. The soil can generally not absorb the amount of water which falls in such a short time, causing intense surface runoff. Further, much water is lost to the atmosphere through evaporation from open soil surfaces. These climatic factors mean that it is important to use the limited amount of rainfall as efficiently as possible. By increasing soil water content supply and retention, crop yields can be improved significantly, and successful crop production can be made possible even in areas of very limited production potential.

Increasing water availability for crops can be achieved by irrigation, but due to the lack of available water resources this is often not an option in African drylands. A more realistic option is to try and utilise rainfall amounts as efficiently as possible for crops. Well known and used soil and water conservation techniques such as terracing helps to prevent runoff and increase soil water content but are maybe not always the best option due to high labour requirements. In dry regions without sources of irrigation and where rainfall is insufficient to cover the water demands of crops water can be harvested in order to increase the available water for crops. Water harvesting and soil moisture retention are cheap and simple options for increasing soil moisture. Water harvesting makes use of surface runoff and can be defined as the collection of runoff for productive purposes, while soil moisture retention aims at preventing runoff and keeping rainwater as much as possible in the place where it falls.

Water harvesting describes methods of collecting and concentrating various forms of runoff. It involves the transfer of runoff water from a land area that is not cropped to supplement the rainfall received directly on the area where crops are grown. Rainwater harvesting is relevant where problems of environmental degradation, drought and population pressure are most evident. Most of this land is located in arid or semi-arid areas, where rainfall is irregular and much water is lost through runoff.

There are two types of catchment areas; 1) within-field where patches or strips of catchments are alternated with cultivated plots, all within the boundary of the cultivated field, 2) external where runoff on land such as grazing land or uncultivated land is collected and diverted in order to supplement the rainfall on the cultivated area. The collected water is then directed onto the cultivated area by small canals or to a storage construction so that the water can be used later. The principles of rainwater harvesting are illustrated below:



The principle of rainwater harvesting for plant production;

A) External catchment area,

B) Within-field catchment (Critchley, 1991).

Water harvesting and soil moisture retention have the capacity to improve food security, income levels and standard of living in dry areas by:

- 1) **Conserving the soil and water resource base:** Runoff which often is a destructive force, causing erosion can through water harvesting be turned beneficial if the runoff is held on the surface and encouraged to infiltrate.
- 2) **Improving crop yields:** When runoff is trapped and encouraged to infiltrate soil moisture availability increases and crops can thereby withstand dryspells and droughts better, leading to higher yields.
- 3) **Improved tree seedling survival and growth rate:** When soil moisture supply is improved, high seedling survival rates can be obtained.

Water harvesting and soil moisture retention practices are highly site specific. Dimension and construction details vary depending on the local situation. This chapter gives a brief introduction to some of some water harvesting and soil moisture retention practices that have proven successful in African drylands.

## RETENTION DITCHES

Retention ditches are large ditches, designed to catch and retain all incoming runoff and hold it until it infiltrated into the ground. They are sometimes also called infiltration ditches. In semi-arid areas retention ditches are commonly used for trapping rainwater and for growing crops that have high water requirements, such as bananas. These crops can be planted in the ditch and thereby get increased supply of moisture. The design of retention ditches is usually determined by trial and error. Often the ditch is about 0.3-0.6 m deep and 0.5-1 m wide. In very stable soils it is possible to make the sides nearly vertical, but in most cases the top width of the ditch needs to be wider than the bottom width. The spacing between the ditches varies according to slope. On flat land the ditches are usually spaced at 20 m and have close ends so that all rainwater is trapped. On sloping land the spacing is between 10-15m and the ditches might have open ends so that excess water can exit. Retention ditches can also be made for the purpose of harvesting water from roads or tracks. The location of such ditches will be specific to the site. When constructing the ditches, the soil is thrown to the lower side to form an embankment that prevents soil from falling back in. In order to stabilize the structure grass can be planted on top of the embankment.

### Conditions

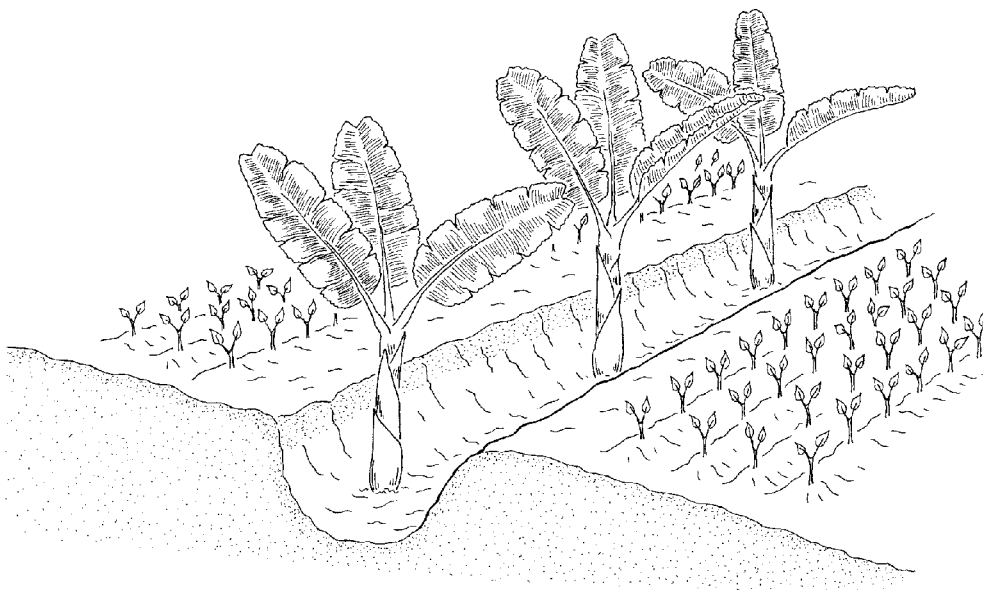
Retention ditches are particularly beneficial in semi-arid areas where lack of soil moisture is a problem. They should be constructed on flat or gentle sloping land and soils should be permeable, deep and stable. Retention ditches are not suitable on shallow soils or in areas prone to landslides.

### Advantages

- Retains runoff and improves soil moisture.
- Reduces soil erosion.
- Makes it possible to grow water demanding crops in dry areas.

### Limitations

- When heavy rainfall occurs the ditches might overflow and brake.
- Labor demanding to construct.
- Need to be maintained and de-silted regularly.
- On unstable land there might be risk of landslides.



Retention ditch planted with banana trees.

## CONTOUR FARMING

Contour farming means that field activities such as ploughing, furrowing and planting are carried out along contours, and not up and down the slope. The purpose is to prevent surface runoff downslope and encourage infiltration of water into the soil. Structures and plants are established along the contour lines following the configuration on the ground. Contour farming may involve construction of soil traps, bench terraces or bunds, or the establishment of hedgerows. The first step in contour farming is to determine a contour guide line. All subsequent water conservation measures are related to the contour guide lines. Contour ploughing ensures that rainfall and runoff are spread evenly over a field by making furrows parallel to the contours. If you don't plough along the contour, water will run down the furrows and erode soils when it rains. Small dams made of earth can be made at regular intervals in the furrows, to trap rainwater and prevent it from flowing along the contour; these are known as tied ridges.

### Conditions

Contour ploughing is successful on slopes with a gradient of less than 10%. On steeper slopes contour ploughing should be combined with other measures, such as terracing or strip cropping. The fields should have an even slope, since on very irregular slopes it is too time-consuming to follow the contours when ploughing.

### Advantages

- Reduces runoff and soil erosion.
- Reduces nutrient loss.
- When using animal draft, ploughing is faster, since the equipment moves along the same elevation.

### Limitations

- Improperly laid out contour lines can increase the risk of soil erosion.
- Labor-intensive maintenance.
- If the soils are heavy with low infiltration capacity, a lot of water might collect, increasing the chance of braking.



Ploughing and furrowing carried out on the contour.

## **WATER HARVESTING BY EXTERNAL CATCHMENT**

Water harvesting through an external catchment involves the transfer of runoff water from a land area that is not cropped to supplement the rainfall received directly on the area where crops are grown. When it rains, large amounts of runoff water are generated from roads, grazing areas and homesteads. Instead of this water being lost through runoff to local streams or land depressions, this water can be diverted to the cultivated fields. Simple storage structures can be dug in the ground to store the water temporarily. This water can then be applied to the crops at a later time when the crops need it. Small-scale water harvesting is most successful when operated as a system with three components: 1) the watershed or catchment area that generates the runoff, 2) the reservoir which holds or collects the runoff, 3) and the serviced area where the harvested water is used for production.

The amount of runoff generated from a catchment area depends on the rainfall patterns and soil and vegetation characteristics. In areas with low rainfall amounts the catchment area needs to be larger. In order for the soil surface in the catchment area to generate substantial runoff grass and vegetation cover should be as limited as possible.

### **Conditions**

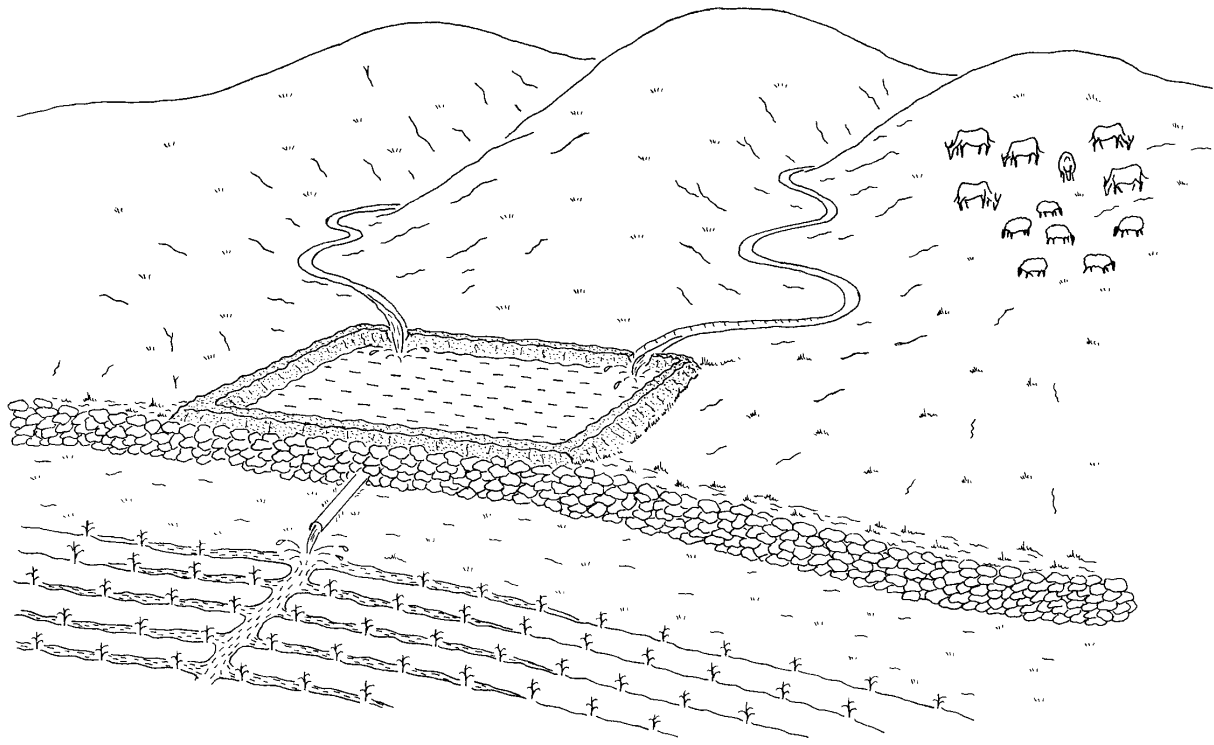
Water harvesting by external catchments is suitable in areas with low rainfall (300-800 mm per year) where there is a lot of uncultivated, open land available. It is not suitable in densely populated areas where most of the land is cultivated. Sites that are communally owned should be properly managed to ensure sharing among the intended beneficiaries. If the area already suffers from erosion problems, large external catchments might not be suitable since the technology does not reduce erosion.

### **Advantages**

- Improves yield security, since irrigation can be carried out during dry spells.
- Increases available water amounts for crops.
- Allows irrigation by gravity (no additional power costs).
- Involves low investment costs per acre.
- Provides alternative uses for offset sacrificed land area.

### **Limitations**

- The storage structure require large amount of labor to construct.
- Large runoff amounts can make the reservoir overflow and brake.
- A lot of water might be lost from the reservoir through evaporation and seepage.
- Poor design and management can lead to erosion and flooding.
- Farmers may be unwilling to sacrifice a portion of their land for a reservoir.
- Engineering knowledge is required.
- Water harvesting on communally owned property might cause conflicts about water rights.



**Water harvesting by external catchment and dam storage structure.**

## CONTOUR FURROWS

Contour furrows are, small earthen banks, with a furrow on the higher side which collects runoff from the catchment area between the ridges. The catchment area is left uncultivated and clear of vegetation to maximize runoff. Crops can be planted on the sides of the furrow and on the ridges. Plants with high water requirements, such as beans and peas are usually planted on the higher side of the furrow, and cereal crops such as maize and millet are usually planted on the ridges.

The distance between the ridges varies between 1 and 2 m depending on the slope gradient, the size of the catchment area desired and available rainfall amounts. The drier area, the larger the distance between the furrows. Small cross-ties in the furrows can be constructed at regular intervals and at right angle to the ridges to prevent flow of runoff and to ensure an evenly distribution of captured water.

### Conditions

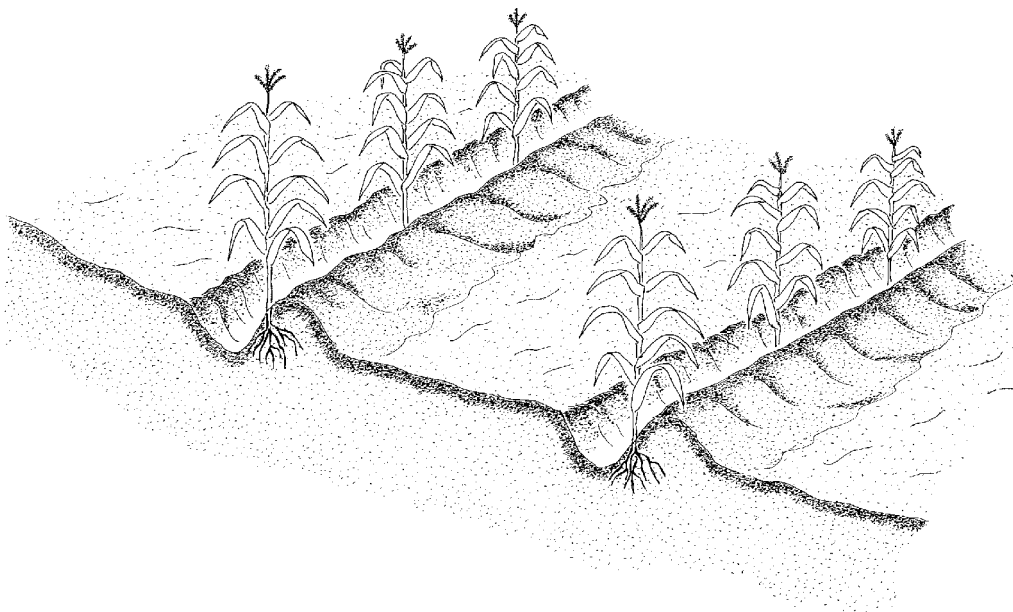
Contour furrows are suitable for areas with annual rainfall amounts of 350-700mm. The topography should be even to facilitate an even distribution of the water. Contour furrows are most suitable on gentle slopes of about 0.5-3%. Soils should be fairly light. On heavier, more clayey soils they are less effective because of the lower infiltration rate.

### Advantages

- Improved soil moisture and water availability for plants.
- Reduced risk of erosion.
- They are easy to make and maintain.
- Relatively low labor requirements.

### Limitations

- Labor requirements are higher than for conventional farming.
- Not suitable for very dry areas since the harvested water is limited.
- When heavy rainfall occurs the ditches might overflow and brake. To prevent this the height of the bund can be increased.
- Land preparation with animal draft might be difficult.
- The bunds and furrows need to be maintained and repaired regularly.



Contour furrows

## STONE LINES

Stone lines along the contour is a popular technology in dry stony areas. Since the lines are permeable they do not pond runoff water, but slow down the speed, filter it, and spread the water over the field, thus enhancing water infiltration and reducing soil erosion. The lines are constructed by making a shallow foundation trench along the contour. Larger stones are then put on the downslope side of the trench. Smaller stones are used to build the rest of the bund. The stone lines can be reinforced with earth, or crop residues to make them more stable. When it rains, soil will start to build up on the upslope side of the stone-line, and over time a natural terrace is formed. The stone lines are spaced 15-30 m apart, a shorter distance being used for the steeper slopes.

### Conditions

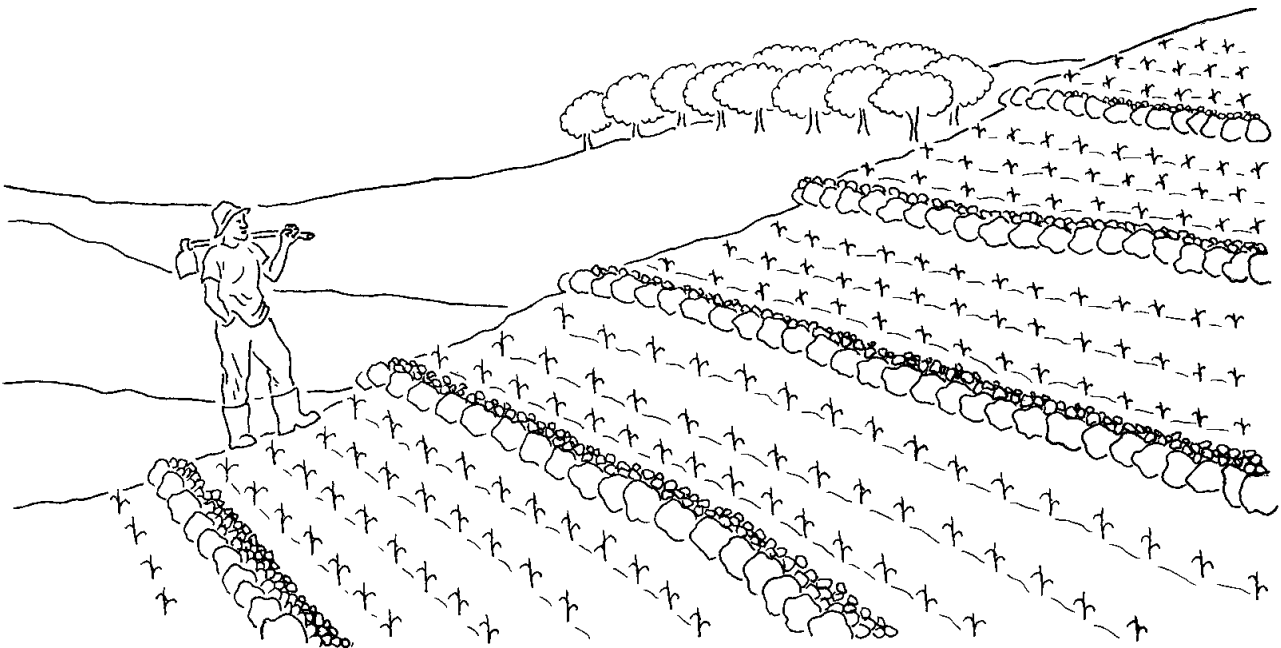
Stone lines are suitable on gentle slopes in areas with annual rainfall of 200-750 mm. They are often used to rehabilitate eroded and abandoned land. Plenty of stones should be locally available. Most agricultural soils are suitable.

### Advantages

- Slows down runoff and thereby increases infiltration and soil moisture.
- Induces a natural process of terracing.
- Reduces erosion and rehabilitates eroded lands by trapping silt.
- Are easy to design and construct.
- Since the structure is permeable, there is no need for spillways to drain excess runoff water.

### Limitations

- Stones might not always be locally available.
- The stone lines might serve as a refuge for rodents and reptiles.
- Construction is labor demanding.



Stone lines along the contour

## GRASS STRIPS

Grass strips is a cheap alternative to terracing. Grass is planted in dense strips, up to a meter wide, along the contour. These lines create barriers that minimize soil erosion and runoff. Silt builds up in front of the strip, and within time benches are formed. The spacing of the strips depends on the slope of the land. On gentle sloping land the strips should have a wide spacing (20-30 m). On steep land the spacing needs to be less (10-15m).

Grass strips can be planted along ditches to stabilize them, or on the rises of bench terraces to prevent erosion. The grass needs to be trimmed regularly, to prevent them from shading and spreading to the cropped area between strips. The cut grass can be used as livestock fodder or as mulch. Many grass varieties can be used, depending on what is locally available. Vetiver grass is a good grass to reduce erosion and resists drought well. Other examples of grasses that can be used are Napier, Guinea and Guatemala grass. Alternatively a local Veld grass can be used. Follow local recommendations!

### Conditions

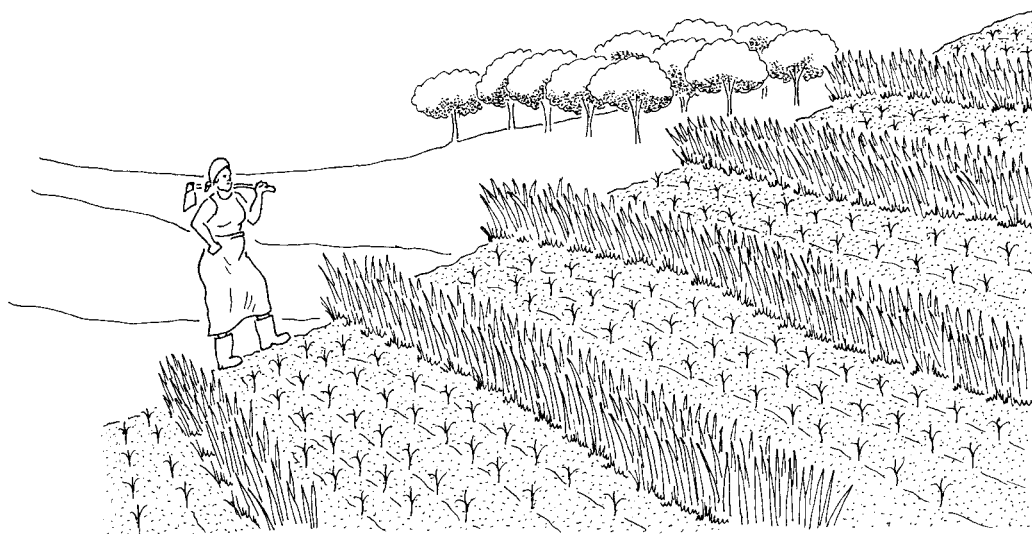
Grass strips are suitable in areas where there is a need of fodder or mulch. If farmers do not have livestock, they have little incentive to plant grasses. Grass strips are not applicable on steep slopes and in very dry areas since grasses might not withstand drought.

### Advantages

- Controls erosion and runoff.
- Increases soil moisture.
- Cut grass can be used as fodder or mulch.

### Limitations

- If not properly maintained the grass might spread and become a weed problem.
- Takes up land that otherwise might have been used for food production.
- High labor requirements for maintaining the grass strips.
- The grasses might serve as a refuge for rodents.
- Planting materials might not be available locally.



Grass strips along the contour

## PLANTING PITS

Planting pits are the simplest form of water harvesting. They have proved especially successful for growing sorghum and millet in areas with minimal rainfall amounts. Small holes are dug at a spacing of about 1 m. During rainstorms the planting pits catch runoff and concentrate it around the growing plant. Crops are planted in the pits and thereby benefit from the increased moisture availability in the pits. Compost or manure is placed in the pits before planting to improve soil fertility. It is not necessary to follow the contour when constructing planting pits. Dimensions of the pits vary according to the type of soil in which they are dug. Usually they are between 10-30 cm in diameter and 5-15 cm deep. In the second year, farmers may sow into the existing holes or, if spacing of the pits is large, they may dig new ones in-between the existing ones.

### Conditions

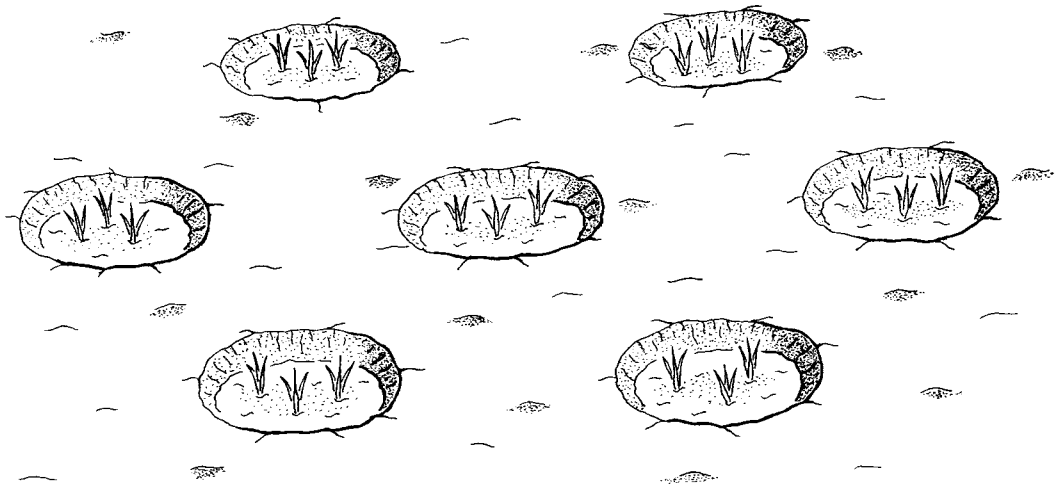
Planting pits have proven successful in areas with annual rainfall of 200-750 mm. They are particularly useful for rehabilitate barren, crusted soils and clay slopes, where infiltration is limited and tillage is difficult. The slope should be gentle (below 2%) and soils should be fairly deep. Where soils are already shallow, they become even shallower when planting pits are dug. In those cases farmers should not plant in the pit, but in top of the ridge of excavated soils in order to maximize rooting depth.

### Advantages

- Trap runoff and increase soil moisture.
- Reduce erosion.

### Limitations

- Digging planting pits is labor intensive.
- Land preparation by animal draft is not possible.



Planting pits

## SEMI-CIRCULAR BUNDS

Semi-circular bunds are earth bunds in the shape of a semi-circle with the tip of the bunds on the contour. The size of the bunds varies, from small structures with a radius of 2 m to very large structures with a radius of 30 m. They are often used to harvest water for fruit trees and are especially useful for seedlings. Large structures are used for rangeland rehabilitation and fodder production. The entire enclosed area is planted. When used for tree growing, the runoff water is collected in an infiltration pit, at the lowest point of the bund, where the tree seedlings also are planted. The bunds are laid out in a staggered arrangement so that the water which spills round the ends of the upper hill will be caught by those lower down.

### Conditions

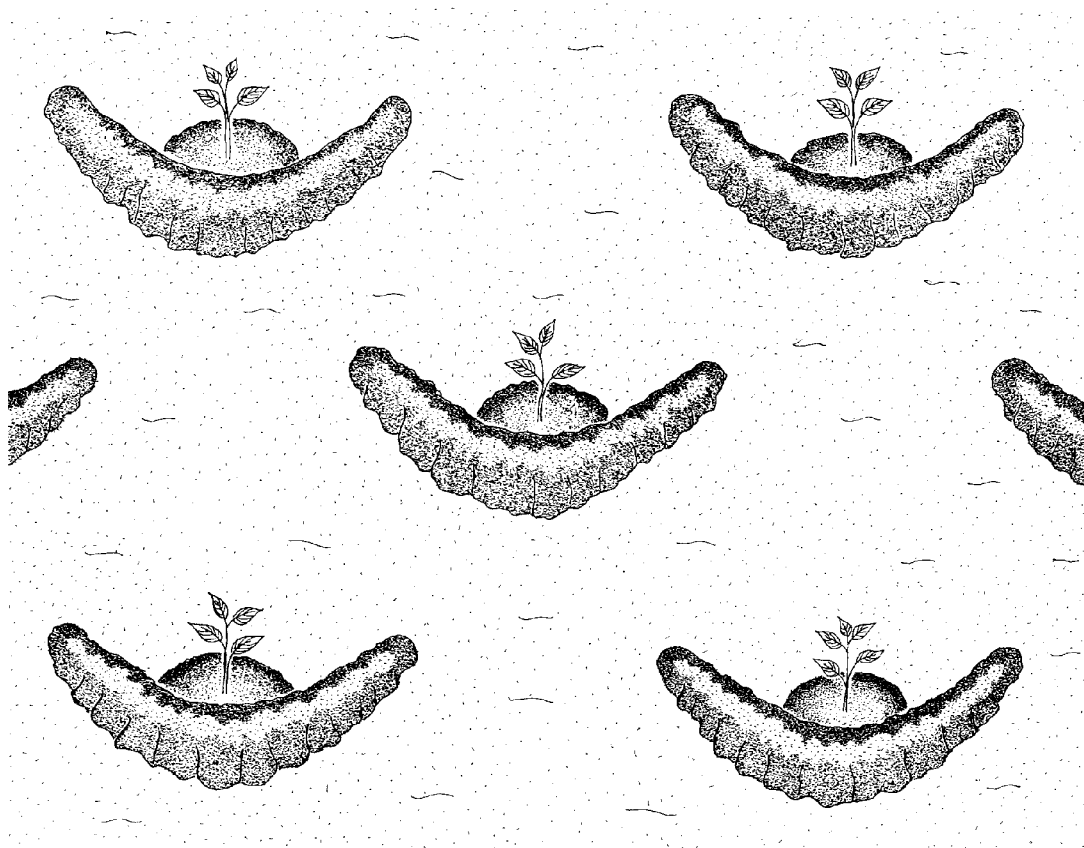
Semi-circular bunds are suitable on gentle slopes (normally below 2%) in areas with annual rainfall of 200-750 mm. The soils should not be too shallow or saline.

### Advantages

- Easy to construct.
- Suitable for uneven terrain.
- Increases soil moisture.
- Reduces erosion.

### Limitations

- Difficult to construct with animal draft.
- Requires regular maintenance.



Semi-circular bunds for fruit production

## EARTH BASINS

Earth basins are square or diamond shaped micro-catchments, intended to capture and hold all rainwater that falls on the field. The basins are constructed by making low earth ridges on all sides of the basins. These ridges keep rainfall and runoff in the mini-basin. Runoff water is then channeled to the lowest point and stored in an infiltration pit. The lowest point of the basin, might be located in one of the corners (on sloping land) or in the middle (on flat land). Earth basins have proven especially successful for growing fruit crops, and the seedling is then planted in or on the side of the infiltration pit. The size of the basin is usually 1-2 m being larger on flat land and smaller on sloping land. In some cases basins of up to 30 m length are constructed. Sometimes grass is planted on the bunds for reinforcement. Manure and compost can be applied to the basin to improve fertility and water-holding capacity.

### Conditions

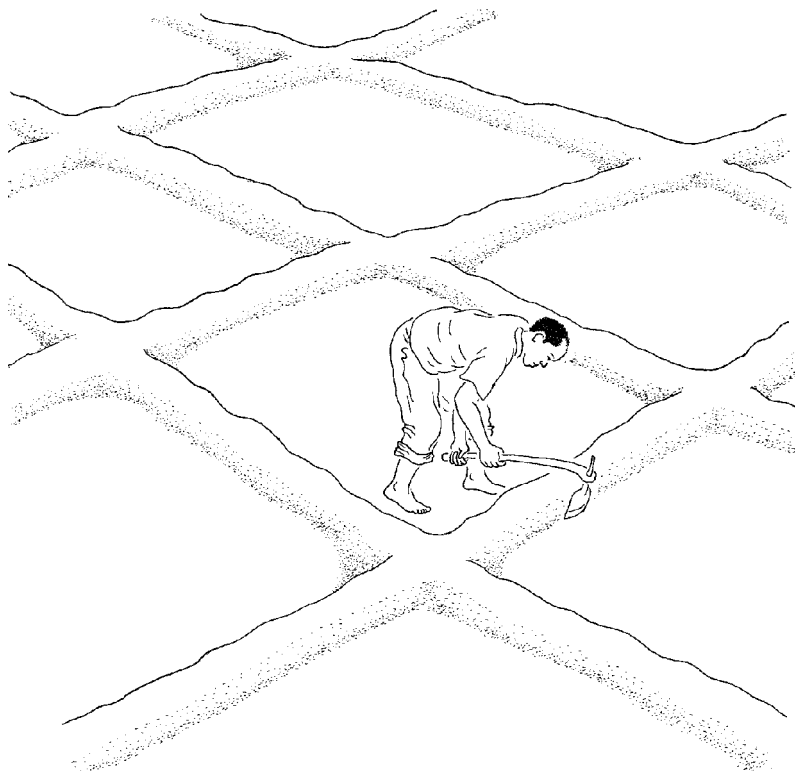
Earth basins are suitable in arid and semi-arid areas, with annual rainfall amounts of 150 mm and above. Soils should be deep, preferably at least 1.5 m to ensure enough water holding capacity. The slope can be from flat up to about 5%. If earth basins are constructed on steep slopes they should be made small.

### Advantages

- The basins are easily constructed by hand.
- Improved soil moisture and water availability for plants.
- No rainwater is lost through runoff and the risk for erosion is reduced.

### Limitations

- Relatively labor demanding.
- Large areas are used for limited production.
- Heavy rainfall events might cause the structures to overflow since there is no outlet for excess water.



Earth basins

## MULCHING

Mulching is done by covering the soil between crop rows or around trees or vegetables with cut grass, crop residues, straw or other plant material. This practice help to retain soil moisture by limiting evaporation, prevents weed growth and enhances soil structure. It is commonly used in areas subject to drought and weed infestation. The mulch layer is rougher than the surface of the soil and thus inhibits runoff. The layer of plant material protects the soil from splash erosion and limits the formation of crust. The optimal propotion of soil cover ranges between 30% and 70 %.

The choice of mulch depends on locally available materials. In alley-cropping systems, hedgerow biomass is often used as mulch, another strategy is to leave crop residues, such as maize stalks on the ground after harvesting. Mulch can be spread on a seedbed or around planting holes. It can also be applied in strips. Large pieces of crop residues should be cut into smaller pieces before application. The mulch may be covered with a layer of soil to protect it against wind.

### Conditions

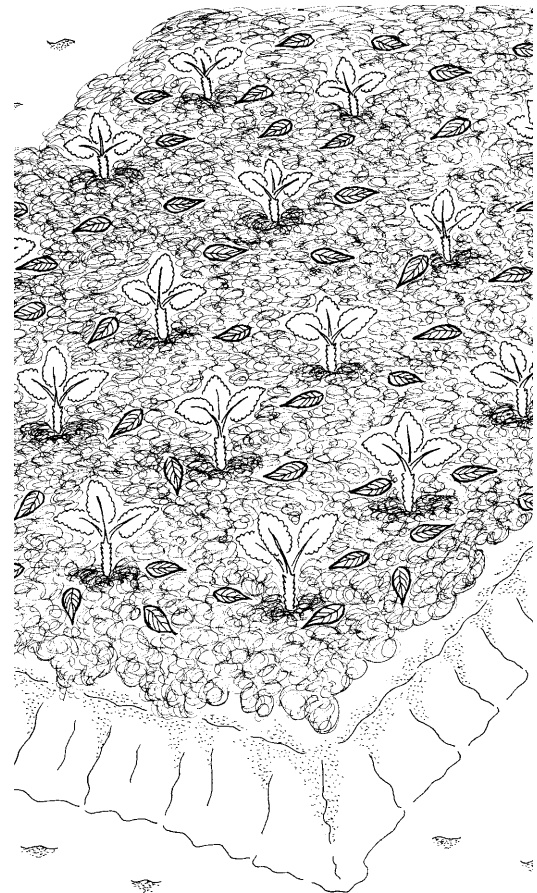
Areas with limited rainfall usually respond very well to mulching. Mulching is not applicable in wet conditions. The soils should have good drainage.

### Advantages

- Increases soil moisture.
- Reduces evaporation from the soil surface.
- Suppresses weeds and reduces labor costs of weeding.
- Reduces high fluctuations in soil temperature, which means improved conditions for micro-organisms in the soil.
- Increases soil organic matter and thereby improves soil structure.
- Protects the soil against splash erosion and runoff.

### Limitations

- Some grass species used as mulch can root and become a weed problem.
- Suitable material for mulch might not always be available.
- If crop residues are used as mulch it might mean a loss of animal fodder.
- Mulching of dried grasses may be a fire hazard.
- Possible habitat for pests and diseases.
- Difficult to spread on steep land.



**Mulching**

## COVER CROPS

Cover crops are usually creeping legumes which cover the ground surface between widely spaced perennial crops such as fruit trees and coffee, or between rows of grain crops such as maize. Often cover crops are combined with mulching. They are grown to protect the soil from erosion and to improve soil fertility. Cover crops protect the soil from splashing raindrops and too much heat from the sun. Most of the plants used as ground cover are legumes, such as different varieties of beans and peas. Pigeon peas and other crops with strong tap roots and longer growing season than maize and beans make good mix and can be used to break hard-pans in semi-arid areas. Over 100 species of cover crops are in use around the world. For the cover crop to compete with the main crop as little as possible the cover crop should be of a low yielding variety. Cover crops should be planted as soon as possible after tillage to be fully beneficial. This can be done at the same time as sowing the main crop, or after the main crop has established, to avoid competition at crop nutrition level.

### Conditions

Cover crops are not very suitable for dry areas, with annual rainfall of less than 500 mm, since they might compete for water with the main crop. Under such conditions it might be better to keep the weeds and natural vegetation as cover.

### Advantages

- Improves soil structure and soil fertility.
- Reduces soil erosion and runoff.
- Suppresses weeds.
- Provides human food and animal forage.
- Improves soil moisture and reduces surface crusting.
- Reduces high fluctuations in soil temperatures.
- Some cover crops can provide good cash income.
- Cover crops can be a good alternative source of much, especially useful in semi-arid lands where crop residue are important animal feed.

### Limitations

- Often require phosphorus fertilizer.
- Compete for water and nutrients with the main crop.
- The dense cover crop foliage might serve as a refuge for rodents.
- Involves additional farm labor and inputs.
- Legumes are rather sensitive to diseases.



**Cover crop grown to cover the soil inbetween maize rows**

## CONSERVATION TILLAGE

Conservation Tillage refers to the practice in which soil manipulation is reduced to a minimum. This practice preserves soil structure and, increases soil moisture availability and reduces runoff and erosion. Conventionally tillage is conducted basically to prepare land for sowing or planting operations but mainly to control weeds. Unfortunately conventional tillage destroys the structure of the soil and compact it. This has negative effects on soil aeration, root development and water infiltration among others. More important, but less noticeable (longer-term process) is the destruction of soil fauna by disturbance and turning over of soil which is in turn exposed to drastic atmospheric and climatic conditions.

After several decades of soil and water conservation efforts in Africa, conservation tillage has been recognised as the missing link between biological methods of agroforestry, farm inputs (fertiliser, improved seed etc.) and mechanical approaches such as terracing. Even with terracing, a substantial amount of soil and water is lost as the capacity for infiltration is drastically reduced by surface crusting of bare soils and tillage induced or naturally generated hard pans. It is therefore not surprising to see farmers complaining about declining rainfall amounts and effect of fertilisers where rainfall records and soil fertility tests prove the opposite.

Conservation tillage takes various forms, depending on the prevailing soil and farming conditions. When introducing conservation tillage, it is important to focus on the needs of the specific farming conditions. Each farmer's plot has specific soil characteristics and management needs. Conservation tillage is defined broadly with regard to four main application principles:

- No soil turning,
- Permanent soil cover,
- Mulch planting (direct sowing),
- Crop selection and rotation.

**No soil turning** includes a *No-till* subsystem where the land is prepared without the use of a conventional mouldboard plough, or a *Minimum-tillage* sub-system where tine based implements are used to open soil to a minimum extent, only to make the insertion of seed possible. Minimum tillage may also be applied to break the hard pans, and where access to equipment is possible, the operation can be advanced to simultaneously insert seed (and even fertiliser) into the soil while breaking the hard pan in the same single pass (see Annex IV). The principle is also applicable for manual (hand hoe) operations where sharp heavy hoes are applied to till only the spots where seeds are to be placed. This operation is referred to as *pitting* or *pot-holing*.

**Permanent soil cover** protects soil from harsh rain drops, fauna-killing radiation, high temperatures and erosion, among other effects. Permanent soil cover can be achieved by *mulch* or *cover crops*. In most cases mulch is derived by leaving a percentage of the crop stover on the farm at harvest time.

**Mulch-planting (or direct-sowing)** is necessary where ground surface is covered with mulch. Recently, smallholder animal drawn mulch planters from Brazil have been introduced in Africa.

**Crop selection and rotation** refers to selecting suitable crops and grow them in sequence, one after another, in the same part of the farm or field. Crop rotation helps to

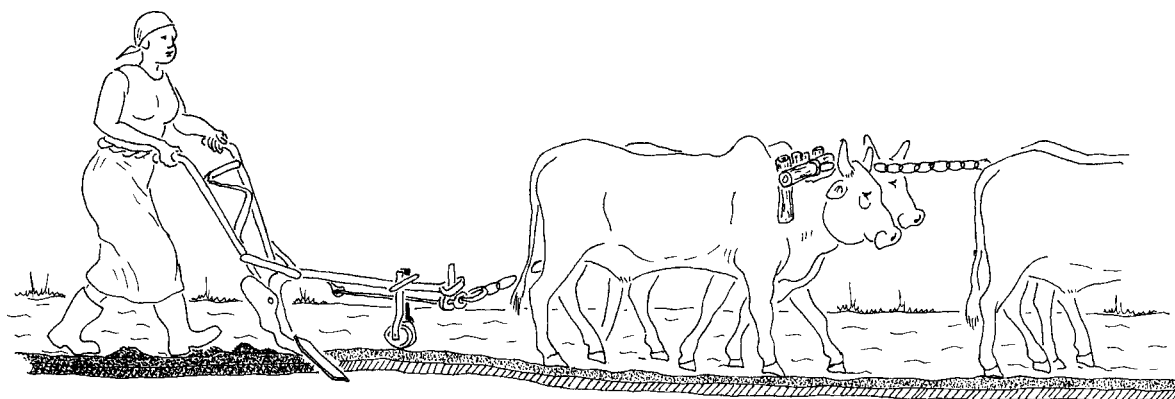
control crop diseases and pests and it also uses nutrient and mineral resource in the soil efficient since different crops will exploit different soil minerals at different times.

### **Advantages**

- Reduces labour and farm power requirements.
- Reduces cost.
- Reduces energy requirements, and increases machine life.
- Increases yields and decreases the need for inputs leading to increased profits.
- Improved traffic-ability in the field and stable soil structure.
- Lessens the direct impact of raindrops on bare soil, thus minimising soil erosion.
- Increases soil moisture availability and thereby improves yield security during dryspells or drought.

### **Limitations**

- Weeds and weed control is a problem in conservation tillage. Especially in early stages (transition phase from conventional tillage) and before mulch cover is established. Herbicides, mechanical cultivators or manual weed control operations can be used for controlling weeds.
- Soil-borne pests and pathogens may prosper during the transition phase due to the change in biological equilibrium. However, once the conservation tillage environment has established, the system is more sustainable than the conventional approach.
- Conservation tillage equipment might not be available locally.



**Minimum tillage by ploughing with a magoye ripper**

**Prepared by Mwamzali Shiribwa and Dr. Pascal Kaumbutho**

## 4. BASIC SCIENCE OF SOIL AND WATER

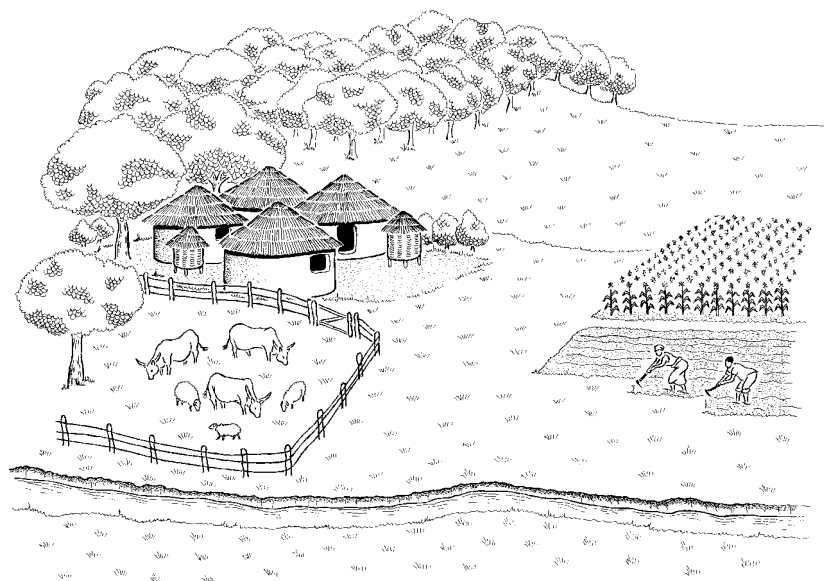
### THE LAND IN YOUR VILLAGE

In a village there are many types of land. Some pieces of land are cultivated, other are forested or used for grazing. Every piece of land is different and has its own qualities and requirements which influence what the land can be used for. Some fields are muddy which makes it difficult to work the land, other sandy which makes them dry out quickly, some have a deep soil layer and produce well when cultivated, other fields have lots of stones and are poor in nutrients etc. As a farmer it is very important to know the characteristics well of the piece of land that is to be cultivated. This will ensure that the fields can be managed in best possible way while being conserved and improved.

These are some examples of different kinds of land:

- cultivated land – land that is cultivated and used for crop production
- cultivable land – fields that could be farmed if they were cleared
- land that can not be farmed – land where crops cannot grow because its too stony, too steep and so on.

In the same way that we adjust our farming practices to the kind of land we have, the land is also influenced and changed by our farming practices. If a forested area is cleared and cultivated, the soil on the land will start to change, at first it will be very productive but after a few season it will be poor in nutrients. If we add manure and organic matter to our soil it will become darker and more productive. Only when we are aware of the effects that our farming has on the land can we modify our practices so that farming does not damage the land and the land continues to be productive year after year.



**The land in your village**

## **EXERCISE – VILLAGE LAND USE MAP**

In this exercise you will make a map of your village and determine the land characteristics of different pieces of land. The map constructed will help you identify problems and opportunities in the village and can be used for planning interventions or actions.

**Time required:** 2 hours

**Materials:** large sheet of paper, coloured pens

### **Procedure:**

1. In groups of about 4-6 persons, draw a simple map of the area on a large sheet of paper. Include roads, paths, hills, valleys, rivers, streams and any other physical features that you can recognise. Mark out the areas that are cultivated, grazed and forested.
2. Mark on the map the location of your farms and note down any specific characteristics of the individual fields. Draw arrows according to how water flows in the village and on individual fields when it is raining, and mark the water collecting points.
3. Discuss the land characteristics of the different fields. Try to relate soil and water conditions of the fields to their location in the village (up on a hill, on the slope, down in a valley etc.).
4. Gather the groups together and discuss the main findings of each group.

### **Questions to discuss:**

- Are differences in soil and water conditions of the fields related to their location in the village?
- How do the land characteristics influence the selection of the crop planted in the village and soil/water management practices?
- How does soil depth and soil moisture vary according to slope and position of the fields?
- Which parts of the village are affected by runoff and erosion?
- Which are the main problems in the different sections of land, and what are the causes of these problems?
- What management practices are currently in use for conserving the land in your village?

## THE SOIL PROFILE

The soil is made up of many different layers. The most obvious part of the soil is its surface zone, but the underlying layers also have significant effects on crops production. The easiest way to examine the soil in depth is to dig a hole. The vertical cross section of the soil that can then be seen is called *the soil profile*. These layers differ from one another in terms of depth, colour, type of soil, porosity and the arrangement of soil particles. As a farmer it is important to be familiar with the layers of soil, since it has big effects on crop growth and influence how the soil respond to different management practices. Farmers use the soil depth profile to decide what crops to grow and how best to cultivate the land. Water and nutrient availability, root development and workability of the soil are all factors that are related to the characteristics of a specific soil profile. A deep soil has higher potential for agriculture since it usually can hold more moisture and nutrients for plants than a shallow soil.

These are the most common layers of soil that might be found in a soil profile on cultivated land:

**Topsoil** – This is the soil visible at the surface. The layer is usually about a hand deep and dark in colour. It is this layer that gets turned over with the hoe or plough when cultivating the land. In this layer you find plant material, such as living roots, dead roots and rotting leaves and stems. This material is called organic matter and is what gives the surface layer its dark colour. The organic matter is transformed into plant nutrients by micro-organisms in the soil. On top of the soil surface a thin layer of dry plant material such as dead plants, leaves and grass is usually found. The topsoil is the most important layer for crops since it is the main supplier of water and nutrients to the plants and most of the plant roots are found here. The deeper this layer is the more fertile is the soil. Through proper tillage and addition of organic matter, the physical condition of the topsoil can be modified to raise its fertility and productivity.

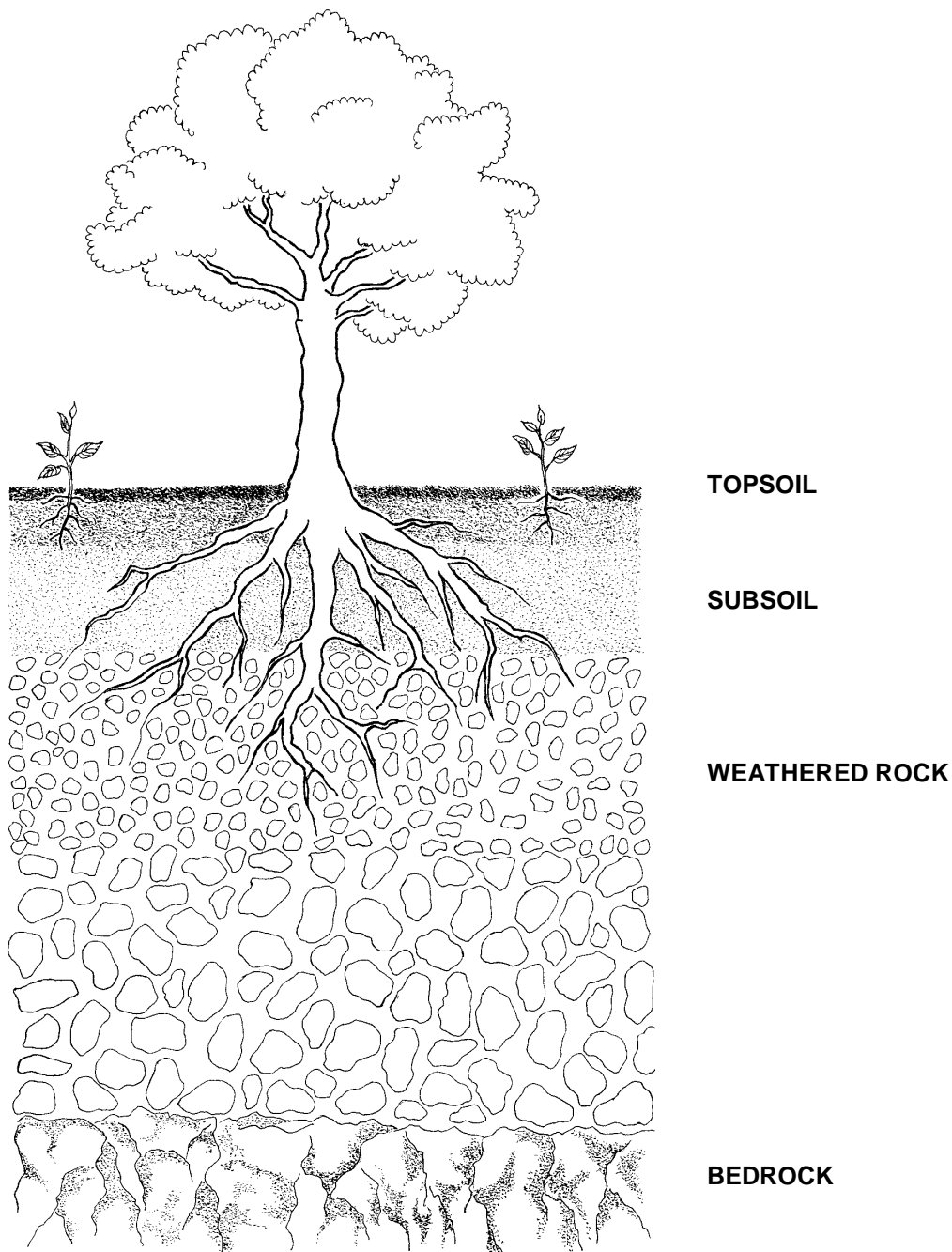
On cultivated land you often find a thin compacted layer right below the topsoil. This compacted layer forms under the depth that the plough or the hoe penetrate and is therefore called the *plough sole*. Every season when cultivating the land this layer gets more and more compacted. The plough sole can have serious effects on crop performance since, if it is too hard, roots and water cannot penetrate it.

**Subsoil** – This is the soil under the surface layer. This layer is lighter in colour than the topsoil and more compact. Roots of crops growing on the surface can be found in this layer and also animals such as the earthworm, termites and different kinds of insects. Crop production is influenced by the root penetration into the sub-soil and by the amount of moisture and nutrients held here. An impermeable sub-soil will restrict root growth and penetration. If the subsoil is deep much water can be stored there and runoff and erosion is reduced. The maintenance of the topsoil and subsoil ensures that fertile soil is available for plant growth.

**Weathered rock** – This is the layer found beneath the subsoil, usually hard and difficult to dig. The layer is made up partly of weathered rock and contains no organic matter. The soil particles are so tightly compacted 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.

**Bed rock** – This is the rock or stone underneath the layers of soil. The bed rock is very hard but changes slowly into weathered rock and then into soil. Ponds of water are often formed in the bed rock and this water can be used by trees during draught or by humans through wells. The bed rock influences the mineral component of the whole soil profile. Thus the mineral nutrients that a soil is able to supply to the plant largely depend on the mineral composition of the bed rock. If the bed rock lacks in some minerals, then the soil formed from it will lack the same mineral.



**Typical soil profile**

## **EXERCISE – SOIL PIT**

In this exercise you will dig a hole in the ground and examine the soil profile. Knowledge about the different layers of soil is important for good soil management. Through the exercise you will get familiar with the different layers of soil and their different characteristics, and learn to understand the relationship between landscape, soil type and soil functions.

**Time required:** 3 hours

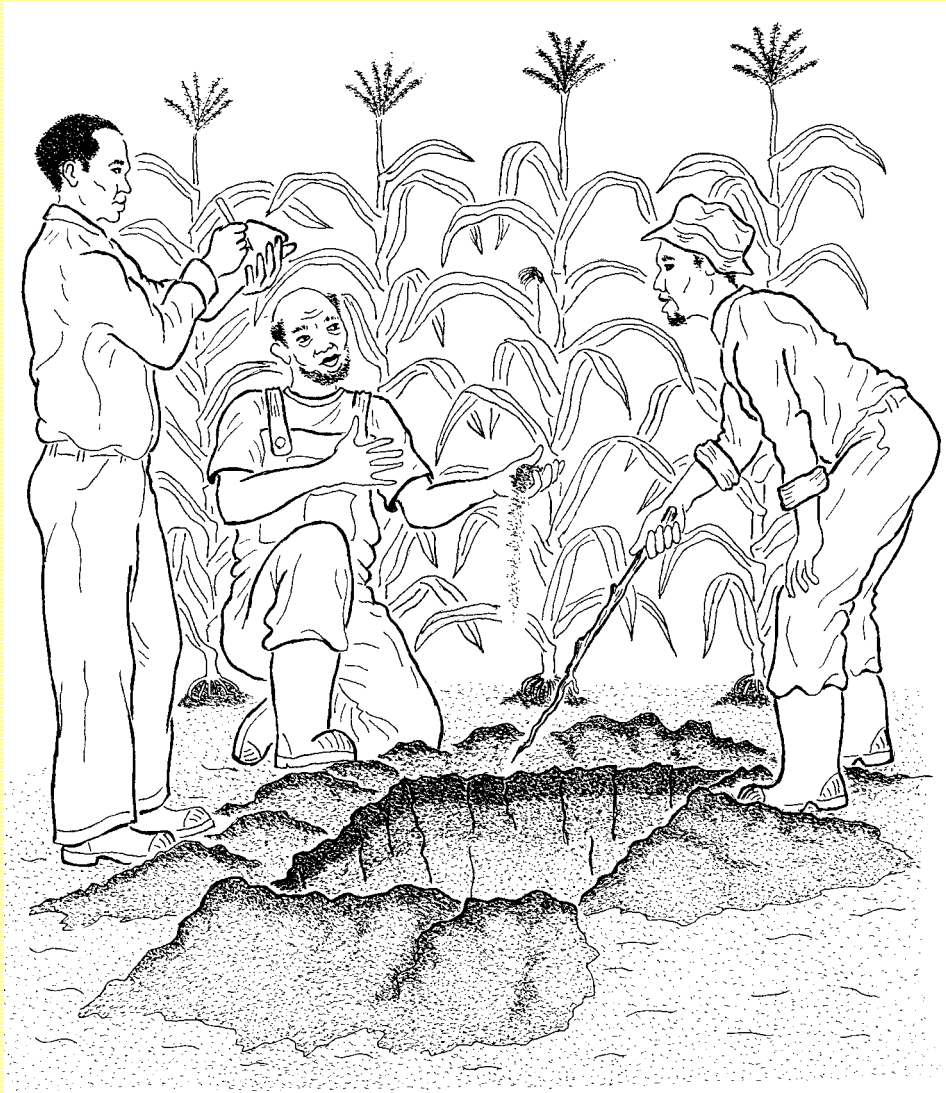
**Materials:** digging tools (spades or hoes), machetes, knives, bottles of water, measuring tape, sheets of papers, coloured pens

### **Procedure:**

1. In groups of about 5-6 persons dig a 1 meter deep and 1 meter wide soil pit. Locate the pits of the different groups in such a way that a variety of soil profiles will be described (different slope, different vegetation cover etc.). Where crops are present one side of the pit should be oriented parallel and adjacent to the crop row so that the roots can be observed in the pit.
2. After finishing digging, describe the soil in your pit, locate and measure the different soil layers, examine the soil in terms of colour, texture, structure, moisture, presence of stones and earthworms, rooting depths, visible minerals, presence of pores and cracks etc. Feel the surface of the layers with a knife and with the hands and take samples of soil at different levels to be passed around in the group for everybody to feel the difference.
3. Draw a sketch of your pit on a sheet of paper and mark the main findings.
4. Get all of the groups together around one pit. The group that dug the pit then explains their findings to the rest of the farmers in their own terminology, and leads a discussion on the soil profile and crop production.
5. Do the same as above at each of the different pits and discuss differences and similarities between the pits.
6. After walking around all of the pits wrap-up and summarise the main findings of the exercise.

### Questions to discuss:

- What were the differences and similarities in within the different soil layers in the pits?
- What implications do different soil layers have on crop growth?
- What implication do different soil layers have on water infiltration and soil moisture?
- How does farming practices affect the soil layers?
- What is the significance of the dark colour of the topsoil, and the depth of this layer?
- How does the soil texture (clay, sand, heavy, light) affect soil moisture availability?
- What affects the rooting depth of plants, and what types of soil layers will stop roots from penetrating deep?
- What is the advantage for crops to have deep roots?
- How does soil depth affect the ability of the soil to retain rainwater?



## **SOIL TEXTURE**

Soil texture means the size of the individual particles of the soil. The texture of the soil varies from one place to another. Some soils are stony, some are sandy, other get muddy when it is raining. Briefly, if the particles are big then the soil is sandy, if the particles are very small then it's a clay soil. Soils with particle size somewhere in-between are called silty soils. Most soils are a mixture of sand, clay and silt and are then called loamy soils.

### **Sandy soils**

Sand is made up of little grains that are very hard, and do not stick together as clay does. Sand is often found in riverbeds and streams. There it is usually white or yellow because it is clean. Sand in the soil is mixed with earth and therefore not as shiny. When it rains the water goes into the soil quickly, and the land does not become muddy. Sandy soils are easy to work, but does not hold much water. They are said to be thirsty soils, when it does not rain they dry out quickly and crops grown on the field start wilting. Sandy soils are equally poor in nutrients and, therefore can not support plant life for long.

### **Clay soils**

Clay is made up of very small particles. Clay can have many colours, of which brown, black and red are the most common. When dry, clay forms a fine dust that is easily carried away by wind and water. Wet clay stick together and is easy to shape and can therefore be used for making pots and bricks. Almost all soils contain clay. The more clay a soil contains the heavier it is said to be. Often the layers further down in the soil profile contain more clay than the topsoil. When it rains, water does not quickly go into the soil and the soil gets muddy. When dry, clay becomes very hard and forms lumps, and sometimes the soil surface cracks. Clay soils are difficult to work but hold water very well. Even when it has not rained for a long time, the soil still feels moist. When growing crops on clay soils the main problem is drainage, the soil often gets waterlogged after rainfall. Therefore these soils support plant life well.

### **Silty soils**

Some soils are neither sandy nor clay soils. They are silty soils. Silt is made up of grains that are not as big as sand grains and not as small as clay grains. Silty soils do not get as muddy as clay soils and have high fertility. They are easy to cultivate but get compacted if worked on when wet and, as a result, frequently produce surface capping. When it is dry they do not dry out quickly and the surface does not crack.

### **Loamy soils**

Loam soils are soils that contain a mixture of sand, silt and clay. These soils display both sand and clay behaviours, and because of their half and half mixture of properties they are important in agriculture. Loamy soils are usually easy to cultivate, have good drainage and are ideal for living organisms in the soil. With sufficient supply of soil moisture, air and plant nutrients loamy soils are very good for crop production.

## **EXPERIMENT – WHAT IS SOIL MADE OF?<sup>1</sup>**

Most soils are a mixture of clay, silt and sand. Since each of these components have very different characteristics and qualities for crop production it is important to know the specific soil mixture of a field, and know which the dominating soil type is. In this exercise we will look at 3 soils and examine what they are made up of.

**Time required:** 2 hour

**Materials:** 3 glasses, 3 soil samples, water, something to stir with

### **Procedure:**

1. Collect 2 handfuls of soil from 3 different fields, one from a valley, one from top of a hill and one from the side of a slope.
2. By looking at, and touching the samples, make a guess of what the soil is made up of.
3. Fill 1/3 of the glasses with each of the soil samples. Thereafter, fill the rest of the glass with water and stir the mixture well.
4. Let the mixture rest for 5 minutes, and then stir it well once again. Put it down and do not touch it for an hour.
5. Look at the soil in the glasses. The soil has now dropped to the bottom of the glass and the water is clear. Several layers of soil have formed. The biggest particles, will be furthest down and the smallest particles higher up. At the bottom of the glass you will have a layer of sand, above that you will find a layer of silt and at the top there will be a layer of clay. If the water is not clear it is because there are still clay particles in the water. If waiting for a long time these particles would also settle down in the top layer. On top of the water you find pieces of leaves and roots floating.

### **Questions to discuss:**

- Was the soil made up of the components you guessed? If not what were the differences?
- Which of the soils would you prefer to cultivate, and why?

<sup>1</sup> Adapted from: The soil, FAO, 1976

## EXPERIMENT – HOW TO “FEEL” THE SOIL TEXTURE<sup>1</sup>

In the field soil texture can be determined by “feeling” the soil. This involves taking a small sample of soil and rubbing it between the thumb and the other fingers. Soil feels very different when touching it, depending on what kind of particles it is made of. In this exercise you will practice to “feel” the soil texture.

**Time required:** 1 hour

**Materials:** soil samples, water

### Procedure:

1. Collect about 5 soil samples from different kind of fields.
2. Remove stones, roots, leaves and seeds from the soil samples.
3. Take a handful of soil, moisten it with water, a little at a time until the soil begins to stick to your fingers. Work the soil in your hand until it is smooth and uniformly moist.
4. Try to form a round ball and a long cylinder. Follow the guidelines below in order to classify the soil sample.
  - *Sandy soil* – The soil does not stick together, has a rough and gritty feel and it is difficult to form a ball. The ball breaks or falls apart easily. A rough cylinder, about 5 cm long and 1.5 cm, wide can be formed but it cracks easily. The soil does not stick to the fingers and has a sandy feel.
  - *Silty soil* - The soil can be formed into a smooth ball and a cylinder measuring about 13 cm long and 0.5 cm wide. The cylinder can be bent into an U or ring but cracks are then formed.
  - *Clay soil* - The soil feels soft and smooth, and can easily be formed into a ball that feels plastic. The soil is stiff to work between the fingers and can be rolled into a thin ribbon. The ribbon can be formed into a ring without the soil cracking. When wet the soil feels very stick and has a soapy feel.

### Questions to discuss:

- What components are the different soil samples made up of?
- Which of the soils would you prefer to cultivate, and why?

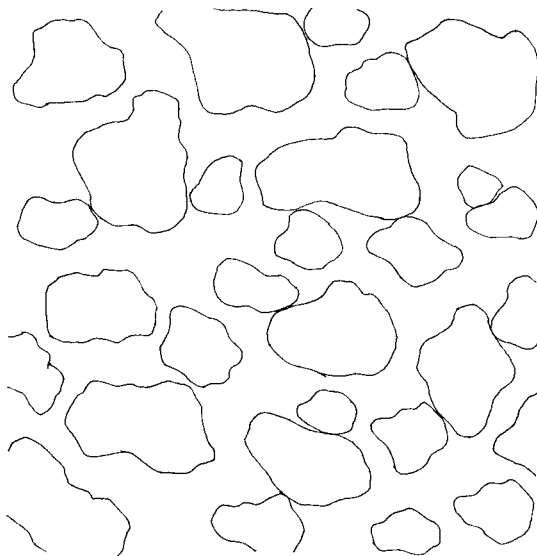
<sup>1</sup> Adapted from: Guidelines and Reference material on Integrated Soil and Nutrient Management and Conservation for Farmer Field Schools, FAO, 2000

## SOIL STRUCTURE

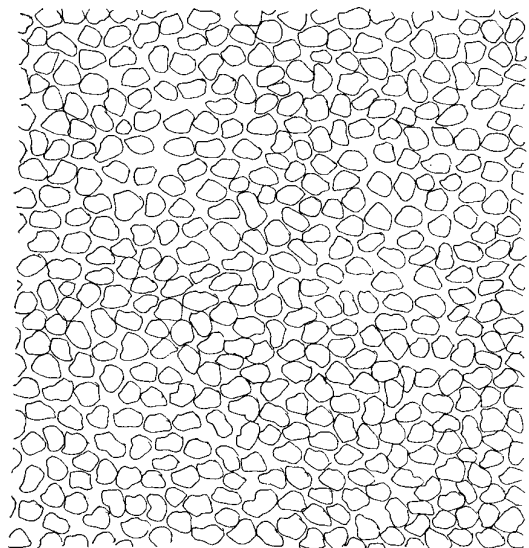
Bricks thrown randomly on top of each other become an unsteady heap. The same bricks, differently arranged and mutually bonded can form a steady house. In the same way soil can be a loose and unstable mixture of particles or it consist of structured patterns of inter-bonded particles that form “chunks” of soil with regular sizes and shapes. In order to understand how our soil behaves, we need not only to study the individual particles but also how the particles are packed and held together. The arrangement and organisation of particles is called *soil structure*.

Soil structure is strongly affected by changes in climate, biological activity, and soil management practices. Roots growing in the soil and animals such as the earthworm help loosening the soil and create channels through which air and water can be transported. On a footpath the soil is very compact and hard. There the structure has been changed due to frequent walking on the soil surface. The structure of a soil greatly influences the performance of crops growing in that soil. If the soil is very compact and hard, roots will find it difficult to penetrate and water will not easily go down into the soil. Sandy soils usually have a loose structure while clay soils have a tight and hard structure. Clay soils on the other hand often have cracks and canals caused by roots and soil animals.

Soil structure influence the pore spaces in the soil. When the particles are closely packed together, the soil has very small pore spaces and, thereby air and water pass through the soil very slowly. In a loosely packed soil with large pores, on the other hand, water and air will easily pass through the soil. A good soil structure in one that is neither too tight nor too loose. Intermediate structured soils with a good balance of soil, air and water are the best for agriculture. Using heavy machinery on wet soils destroys the structure and makes the soil compact. This results in high incidences of surface runoff and erosion.

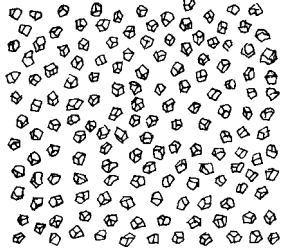
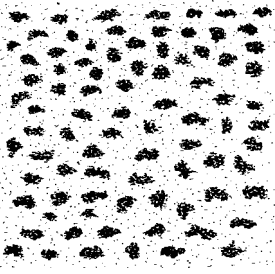
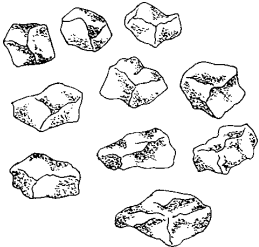

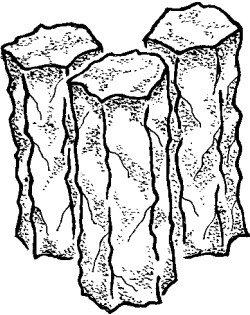


**IN SAND PORE SPACES ARE LARGE**



**IN CLAY PORE SPACES ARE SMALL**

There are various types of soil structure according to the arrangement of particles and the pore spaces in the soil. Some of the most common types of soil structures are<sup>1</sup>:

<p><b>Single-grained structure</b></p> 	<p>This is a basic structure which forms no aggregates or lumps, meaning that particles are not cemented together. It is mostly found in topsoil of sandy soil and arid climates.</p>
<p><b>Crumb or granular structure</b></p> 	<p>These structures consist of small, soft porous aggregates of irregular shape, not closely fitted together. The aggregates are normally loose and easily shaken apart. Very porous structure is called crumb, and less porous structure is called granular. These structures are found in surface soils, and are influenced by cultivation and other management activities by man.</p>
<p><b>Blocky structure</b></p> 	<p>This structure resembles the blocks used in construction. They have six irregular faces. Aggregates easily fit together along vertical edges.</p>
<p><b>Platy structure</b></p> 	<p>In this structure aggregates are arranged on top of one another in thin horizontal or flat plates. The plates often overlap and thereby make root and water penetration difficult. This structure is mostly found in top horizon of soils in the forest or in clay soils.</p>
<p><b>Columnar or Prismatic structure</b></p> 	<p>In this structure, aggregates are arranged in vertical, cylindrical columns or pillars. These pillars vary in size and length. Columnar pillars have rounded tops and are commonly found in the subsoil of soils with poor drainage. Prismatic pillars are have flat tops and are commonly found in the subsoil of soil with fine texture and in semi-arid soils.</p>

<sup>1</sup>Source: Hillel, Introduction to soil physics, Academic press, 1982

## **EXPERIMENT – SOIL STRUCTURE ANALYSIS**

In this exercise you will examine different kinds of soil and discuss soil structure.

**Time required:** 1.5 hours

**Materials:** Shovels, paper, pens

### **Procedure:**

1. In groups of 4-6 persons, walk to a piece of land; a cultivated field, grazing land or forest area.
2. Dig up a square block of soil, about two hands wide. Try not to disturb or break the block.
3. Examine the structure of the block. Brake of pieces of the block with your hands and study the shape and feeling of the pieces. Examine if the soil has a loose structure or if the particles are bound hard to each other. Look for channels and canals in the soil where water and air can pass through.
4. Walk around to 3 or 4 pieces of land fields and do the same as above.

### **Questions to discuss:**

- What differences and similarities in soil structure did you find on the different fields?
- Considering the soil structure of the different fields, on which fields do you think that roots will find it easy to grow. How will root development differ on the different fields?
- What consequence do you think the soil structure on the different fields has on the infiltration of water?

## **SOIL AIR**

Air is present in spaces (pores) between crumbs and particles. This air is known as soil air. Soils with large particles, like sandy soils, have larger air spaces while those with small particles like silt have few and small air pores. Air is necessary for plant growth since roots need air to breath. Without air, roots die and crops do not grow well. Air is also needed by small animals living in the soil such as the micro-organisms, which need air to breath and carry out their activities of braking down organic matter to humus. Humus is needed for a good soil structure and it makes it easier for air to circulate in the soil. If the soil is too compact, or if all the air spaces are filled with water, air cannot circulate well. By working the soil or making ditches to get rid of surplus water you can increase the amount of air in the soil.

## EXPERIMENT – FINDING OUT THE AMOUNT OF AIR IN THE SOIL<sup>1</sup>

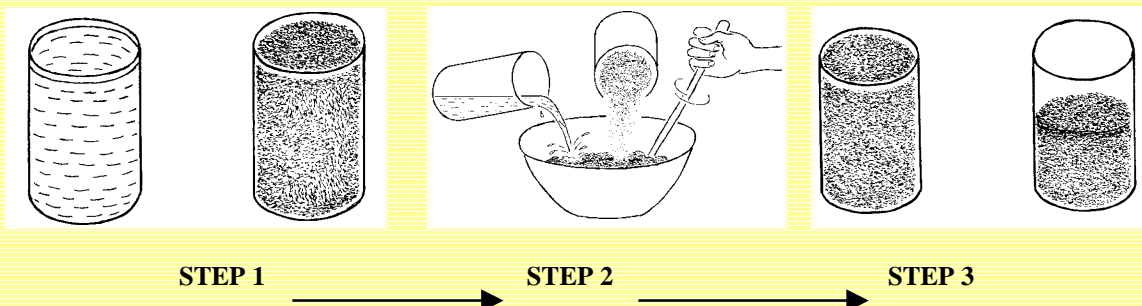
In this experiment you will find out the amount of air in different kinds of soils.

**Time required:** 1 hour

**Materials:** two small tins, one large bowl, tool for stirring, water, knife, nail, soil samples

### Procedure:

1. Get two empty, cylinders, say coffee or margarine tins. Perforate one of the tins with a nail at the bottom end, putting 5-6 holes in it.
2. Turn the perforated tin upside down and press the open end firmly into the ground until the tin is completely filled with soil. Turn the tin upright and level the soil at the brim of the tin with a knife. The soil filled in the tin, now appears in the same way it is normally packed in the ground.
3. Fill the other tin with water.
4. Mix all the soil and water from the two tins in a bowl and stir the mix until no bubbles of air are seen to escape. Let the mixture in the bowl rest for a few minutes and then carefully pour the mixture back into the two tins. First fill one of the tins and then continue pouring into the second one.
5. Make a mark on the second tin at the height of the water level. The volume of air that was in the soil sample is now the same as the empty space between the water level and the top of the cylinder in the second tin.
6. Repeat the experiment with other soil types (clay, loam, sand).
7. Discuss the results and compare the amount of air in different types of soils.

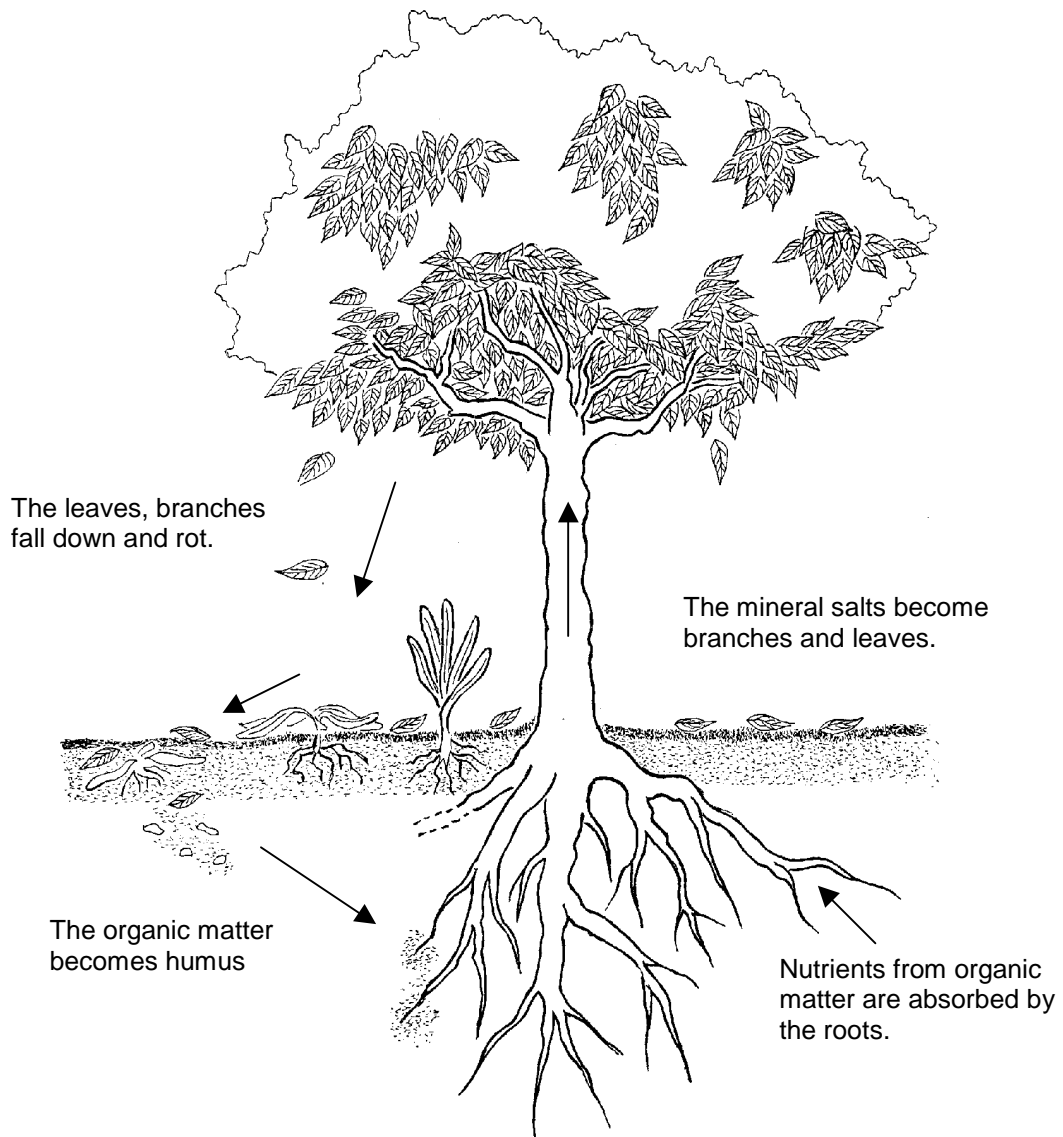


<sup>1</sup> Source: Secondary agriculture, Kenyan Institute of Education, 1999

## ORGANIC MATTER AND HUMUS

Soil organic matter is material that originates from plant and animal remains, such as crop residues, leaves, stems, roots and farmyard manure. When the dead materials rot, they are decomposed and broken down by micro-organisms. Organic matter that has fully undergone decomposition is called *humus*. The origins of the materials after formation of humus cannot be recognised. Humus is dark in colour and very rich in plant nutrients. It is usually found in the top layers of a soil profile. There are many important functions of organic matter in the soil. Some of the most important ones are:

- It increases soil fertility since it slowly continues to release nutrients for plants.
- It binds the soil particles together, thus improving the soil structure and aeration.
- It acts as a sponge in the soil, retaining soil moisture. Soils with high organic matter content can hold more water than those low in organic matter.
- It provides food for micro-organisms living in the soil.
- The dark colour of humus absorbs heat from the sun, thereby maintaining a good soil temperature.



**Humus returns the mineral salts to the plant**

## **WATER AND FARMING**

Water is the most fundamental and basic requirement for any form of life. Without water nothing can live. It plays a major role in the production activities in the farm and plants are to a large extent made up of water. The amount of water that different plants require varies from one type to another and is also dependent on other factors such as, stage of growth, plant physiology, weather conditions and so on.

A good supply of water is an integral part of farming. Water management is therefore an important part of a farmer's life. There are three types of sources of water for farming, namely, surface-, ground- and rain water:

*Surface water* is water that is found in rivers, streams, lakes and dams. Rivers and streams originate from water catchment areas such as mountain, hills and forested areas. They are either temporary or permanent. Many farmers depend on rivers and streams for their water supply. Lakes are huge collections of water from rivers, streams, springs or rain.

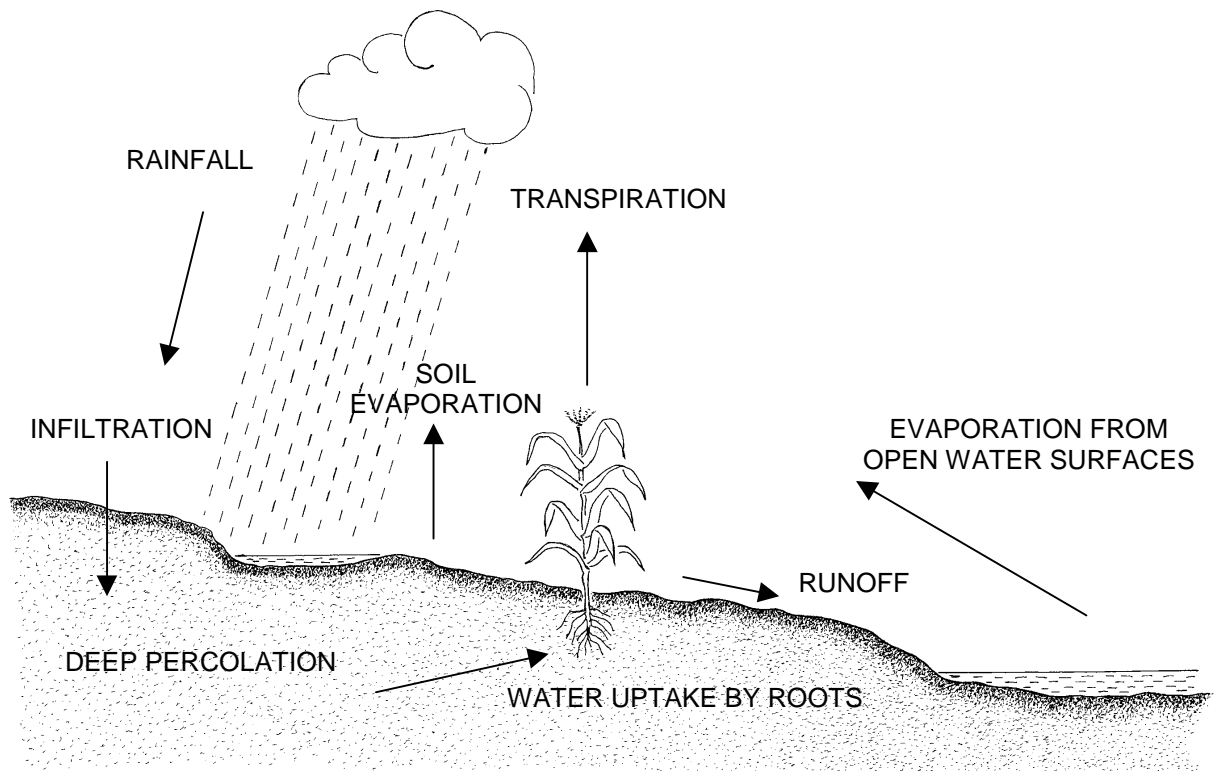
*Ground water* is water that originates from natural bodies of water in the ground. This water can be accessed by natural springs or by manmade wells and bore holes. The depth under the surface that groundwater is found can vary between a few meters to several hundred meters.

*Rain water* is the main source of water for farmers. In many areas however the rains are not reliable and the rainfall might not be enough to support the crops. Water harvesting and soil moisture retention practices are a way of making the most out of scarce rainfall.

## **THE CIRCULATION OF WATER**

Water can not be created, or destroyed. It can only be transformed into different forms. The water that you find in your local stream might have once melted from the top of a snow covered mountain, then been absorbed by a growing plant, gone up in the atmosphere by the plant breathing, formed a cloud and rained back down on the earth and formed the stream that is now running in your village. The circulation of water from the earth's surface to the atmosphere and back again is called the *hydrological cycle*.

Water from the earth's surface evaporates and forms water vapour which rises up to the atmosphere, cools and condenses to form clouds. When these clouds are saturated, they fall down to the earth as rain. This water can then be used by plants and animals upon reaching the earth's surface, or it may collect in water bodies after runoff, or might enter the ground through infiltration to form groundwater. The remaining part of the water may be held by the soil particles and absorbed by plants then lost through transpiration from the plants or evaporation directly from the earth's surface of the soil.



**The hydrological cycle**

Lack of water is not always the primary constraint to crop growth in dryland areas. Poor distribution of rainwater and low capacity of water uptake by plants can reduce yields dramatically. Of the total rainfall in African drylands about 30-50 % goes back to the atmosphere by evaporation. Surface runoff accounts for about 10-25 % and deep percolation about 10-30 %. This leaves only about 15-30 % of the total rainfall for water that can be taken up by plants and used for crop growth (Rockström and Falkenmark, 2000).

In order to maximise yields a manipulation of rain water distribution is necessary. The amount of water that goes through the plant is directly linked to yield levels and available water resources should thereby be redirected in such a way that transpiration accounts for as large a part as possible of the total available water. Runoff and evaporation rates can through farm management be reduced in order to increase available soil water content for crop growth. This can be achieved by appropriate water harvesting and soil moisture retention practices.

## **EXERCISE – THE CIRCULATION OF WATER AND RAINFALL PATTERNS**

In this exercise you will analyse the movement of water in your village, and discuss the rainfall patterns.

**Time required:** 1 hour

**Materials:** paper, pens, the village map

### **Procedure:**

1. Use the village map elaborated in a previous session, to determine where water is found in the village. Make sure that all rivers, streams and points where water collects are included in the map.
2. By using the map, discuss how water moves in the area.
  - What happens when it is raining, where does the water go?
  - Which directions does runoff flow in the area?
  - How deep is the groundwater at different places in the area?
  - Compare the water situation in the village in the dry season and in the rainy season
3. Analyse the rainfall patterns in the area by making a calendar of the year and mark out the distribution of rainfall throughout the year. Discuss the characteristics of rainfall in the area:
  - Is the rainfall distributed evenly within a season or are dryspells common?
  - What is the normal intensity and duration of rainfall events?
  - How do rainfall patterns vary between different years?
  - Has there been a change in rainfall pattern over the years?
4. Discuss the effects that local conditions of water movements and rainfall patterns have on crop production in the area.
5. Summarise the main findings of the discussion.

## INFILTRATION OF WATER

When water is applied to the soil surface, whether by rain or by irrigation, some of the water penetrates the surface and is absorbed by the soil, while some flows over the surface as runoff. Of the water that penetrates the surface some will be taken up by plants, some will return to the atmosphere by evaporation and some will seep downwards and recharge the groundwater reserves. *Infiltration* is the term for the process of water penetration into the soil. The rate at which water can penetrate the soil determines how much water will enter the root zone and how much, will run off. If infiltration is restricted the risk for erosion is increased. Knowledge about the infiltration process and how it is affected by physical conditions of the soil and the use of land is therefore important for efficient soil and water management.

Soil texture has a significant effect on the infiltration of water. Water infiltrates more easily through the larger pores of a sandy soil than for example through the smaller pores of a clay soil. That is why sandy soils are said to be thirsty soils. If a big rainstorm falls on a clay soil, runoff will occur, but if the same rainstorm falls on a sandy soil there will be no runoff.

The structure of a soil also influences the infiltration capacity. Soil structure refers to the way that individual soil particles stick together to form lumps or aggregates. The size and distribution of “cracks” between the aggregates influence the infiltration capacity of a soil: a soil with large cracks has high infiltration rate.

The infiltration capacity of a soil also depends on the conditions of the soil surface. On some soils, a thin but dense and compact layer on top of the soil is found. This effect is often called sealing, and is usually created when raindrops hit the soil surface. The force of the raindrops cause a breakdown of the soil aggregates and the fine soil particles clog the pores of the surface. Surface sealing greatly reduces the infiltration rate of a soil. Soils with a high clay or loam content are most prone to sealing. Coarse, sandy soils are less prone to it. A farmer can increase the infiltration rate in the cultivated area by keeping the soil surface rough by using some form of tillage or ridging practice.

Vegetation has an important effect on the infiltration rate of a soil. A dense vegetation cover protects the soil from the impact of the raindrops and reduces the sealing of the soil, thereby increasing the infiltration rate. The roots and organic matter in the soil make it more porous and increase the infiltration rate. Vegetation also slows down runoff, giving water more time to infiltrate.

The slope also affects the infiltration rate. The steeper land, the more runoff will occur, while on flat land runoff will move slower and the water thereby has more time to infiltrate.

## EXPERIMENT – COMPARISON OF WATER INFILTRATION RATES ON DIFFERENT SOILS

In this experiment you will measure and compare the infiltration rates on cultivated land and non cultivated grazing land.

**Time required:** 1,5 hours

**Materials:** Two infiltration rings (see picture below), made out of metal with a diameter of at least 20 cm and a height of at least 15 cm (the rings can be made out of oil cans, large tins, or metal sheets), water source, two 10 litre buckets, watch, paper, pens and hammer.

### Procedure:

1. Decide on two sites for carrying out the experiment, one site should be on a cultivated piece of land, and the other site on a non cultivated grazing area.
2. At each site, carefully push the infiltration ring about 10 cm into the ground. If the soil is hard use the hammer, but try to make sure that the soil along the sides of the rings is disturbed as little as possible.
3. Record the starting time and start pour 10 litres of water in the ring in such a way that a layer of about 1 cm of water covers the soil until the 10 litres infiltrate completely, whereby the ending time is recorded.
4. Analyse the results and discuss the reasons for the difference in time for the water to infiltrate into the two soils.
5. Verify the differences in infiltration rate of the two soils, by looking at them and feeling their texture in your hands.

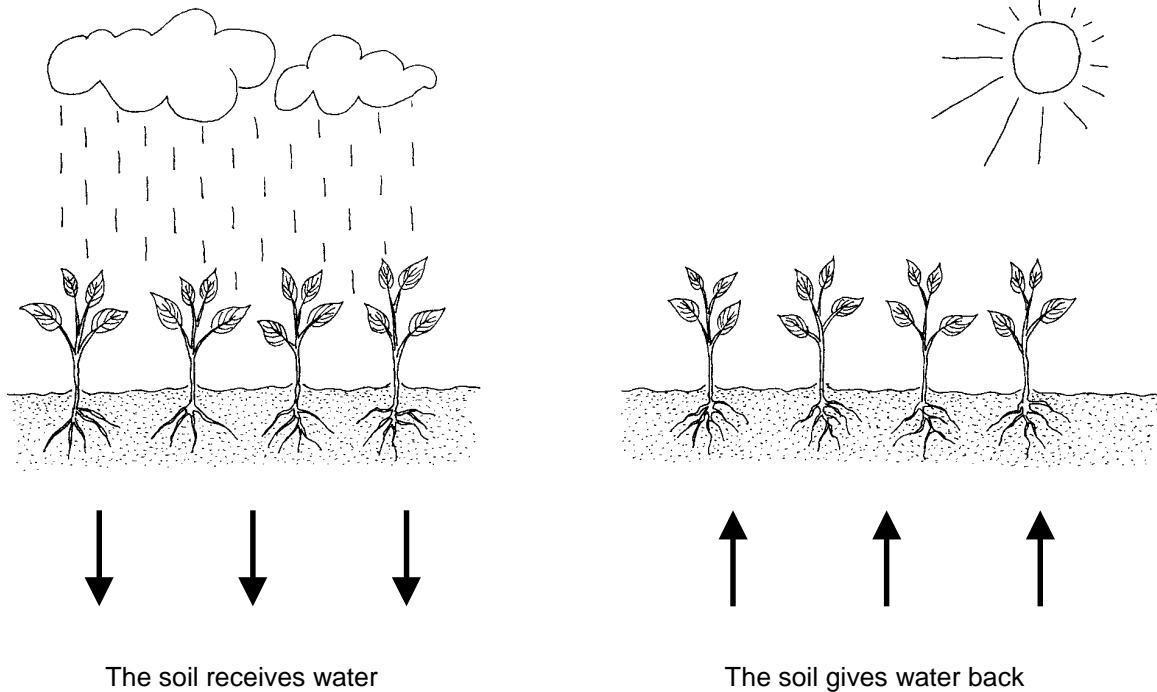
### Questions to discuss:

- What different factors affect the infiltration rate of a soil?
- How can the infiltration rate be manipulated by management practices?
- What impact does the infiltration rate have on runoff and soil erosion?



## WATER IN THE SOIL

The soil of a cultivated area should not only have high infiltration rate, but also have a high capacity to store the infiltrated water and to make this water easily available to the crops. When it doesn't rain, the plants must be able to find water in the soil, thus the soil must build up reserves of water.



**Good soils build up reserves of water and give it back to the plant when necessary.**

The capacity of a soil to store water depends strongly on the soil properties. Clay soils have many very small pores and can store moisture for a long time, while sandy soil with relatively few but large pores can not store moisture for long. Soils with a high content of organic matter can store large amounts of water. Also soil depth is an important factor, determining the storage capacity of a soil. The deeper the soil profile, the more water can be stored. The amount of water in the soil also governs the air content of the soil, thus affecting the breathing of roots and the activity of micro-organisms.

Water in soil moves in all directions. During wet conditions, as after a rainfall, water will be flowing downwards in the soil profile. However, during dry conditions, water will rise in the soil, going from deeper soil layers up to the soil surface where it will evaporate into the atmosphere. The soil also moves sideways. If you make a hole in the earth and then pour water into the hole, the water goes into the hole from above downwards, but it also makes the sides of the hole wet. It thus moves sideways as well as downwards.

## EXPERIMENT – SOIL LUMP RISE<sup>1</sup>

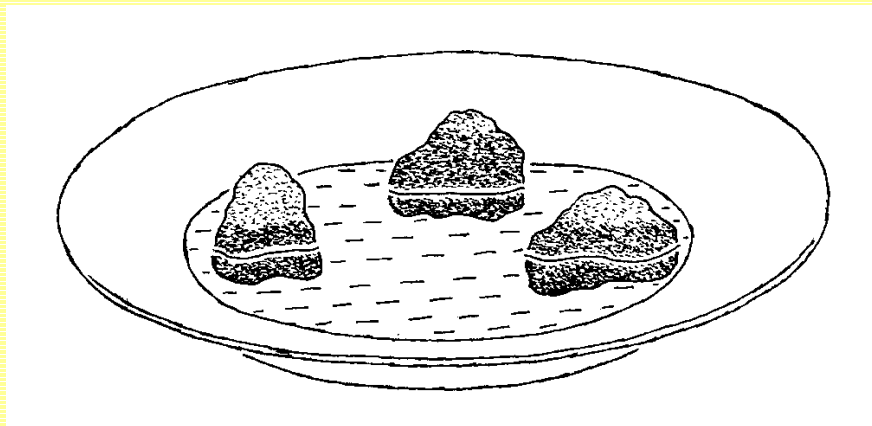
During dry conditions, water in the soil will rise from wet subsoil or from ground water reserves up to the roots. This process is demonstrated in following experiment.

**Time required:** 30 min

**Materials:** plates, a few small lumps of soil, water

### Procedure:

1. Put a little bit of water in different plates.
2. Take some lumps of soil from different fields, and put them in the plates.
3. Watch how the water rises in the lumps of soil.
4. Discuss the reasons for why water rises more quickly in some of the lumps and the effects this has on crop production on those soils.



<sup>1</sup> Adapted from: The soil, FAO, 1976

## **EXPERIMENT – SOIL TIN TEST TO DETERMINE THE CAPACITY OF A SOIL TO HOLD WATER**

In this experiment you will discover that different soils have different capacity to hold water.

**Time required:** 45 min

**Materials:** three small containers, knife, nail, volume graded water container, hammer, shovel

### **Procedure:**

1. Get three empty containers, for example coffee or margarine tins.
2. Perforate the tins with a nail at the bottom end, putting 5-6 holes in them.
3. Select three places for taking the soil samples, one sandy soil, one clay soil and one soil with high organic matter content.
4. On each of the soil, turn one of the perforated tins upside down and press the open end firmly into the ground until the tin is completely filled with soil. If the soil is hard use a hammer to get the tins into the soil.
5. Turn the tin upright and level the soil at the brim of the tin with a knife. In order to not loose any soil in the tin it might be necessary to hold a shovel under the tin while removing it. The soil filled in the tin, now appears in the same way it is normally packed in the ground.
6. Pour water over the soil in the three tins with the volume graded water container. Be careful so that no water overflows and escapes on the sides of the tins. Stop pouring when water starts to come out of the bottom of the tins. All the empty pore spaces in the soil are now filled with water and there is not room for any more water.
7. Measure the water amount that was needed to fill each container and thereby evaluate which soil that can hold most water.
8. Summarise the findings of the experiment.

### **Questions to discuss:**

- Which soil could hold most water?
- What effect does the water holding capacity have on runoff, erosion and plant growth?
- Which factors determine the water holding capacity of a soil?

## EXPERIMENT – COMPARISON OF CLAY, SAND AND ORGANIC MATTER TO RETAIN WATER<sup>1</sup>

In this experiment you will compare the capacities of clay, sand and organic matter to retain water.

**Time required:** 1.5 hours

**Materials:** Three soil samples of about 1 kg each; one clay soil, one sandy soil and one soil with high organic matter content. The samples should have dried in the sun for a few days. Scale or spring balance accurate to within at least 50 g, 3 clean dry cloths, a big bucket or a barrel full of water.

### Procedure:

1. Weigh 0.5 kg of each soil material and place it in separate, but similar cloths. Tie the cloth together so that it forms a bag with the soil sample in and weigh the “bags” with the soil in them.
2. Immerse the three “bags” in water and leave them there for 10 minutes.
3. Remove the “bags” from the water and hang them up until most of the dripping has stopped.
4. Weigh the three bags again and record the weight.
5. Calculate the difference between the initial weights of the bags with dry soil and the final weights. The difference in weight is equal to the amount of water absorbed by the soil.
6. Summarise the findings of the experiment, record the water amounts retained in the different soils in following table and discuss the results:
  - Which soil could hold most water?
  - What effect does the water holding capacity have on runoff, erosion and plant growth?
  - What factors determine the water holding capacity of a soil?

	Dry weight	Wet weight	Weight difference
Sandy soil			
Clay soil			
High OM soil			

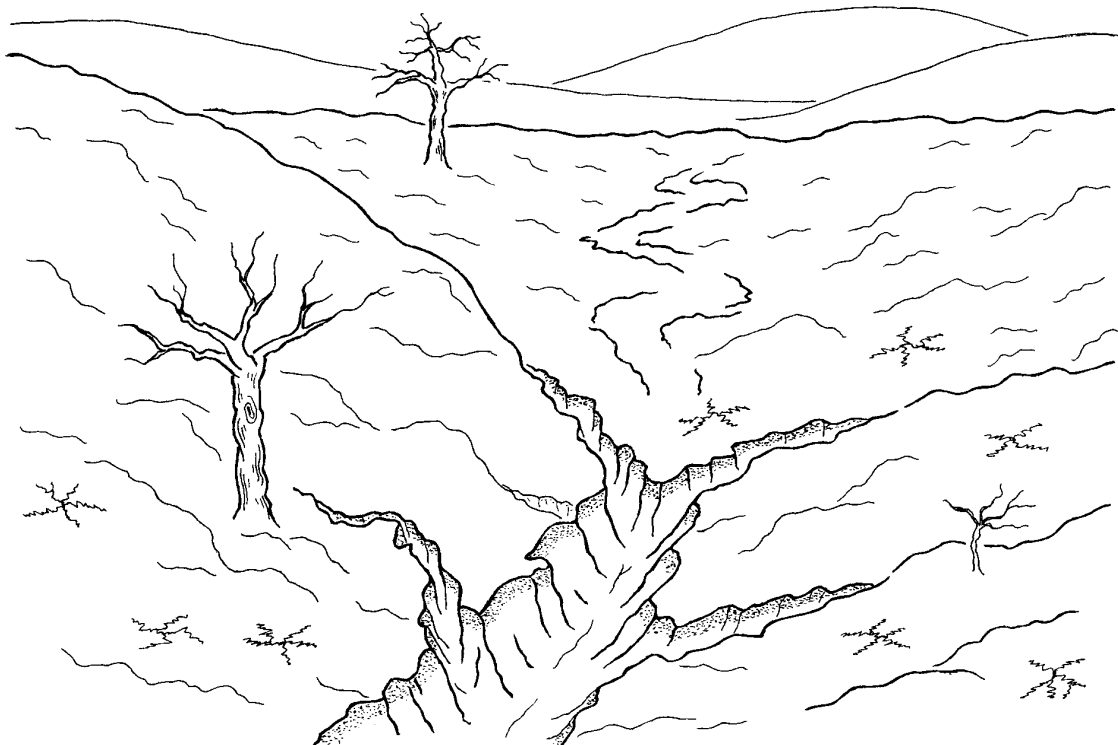
<sup>1</sup> Source: Guidelines and Reference material on Integrated Soil and Nutrient Management and Conservation for Farmer Field Schools, FAO, 2000

## RUNOFF

Whenever the soil receives more water than the rate of infiltration, free water tends to accumulate over the soil surface. This water collects in depressions, thus forming puddles. When the surface storage is filled and puddles begin to overflow runoff starts. The term surface runoff thus represents the portion of the water supply which neither is absorbed by the soil nor accumulates on the surface, but which runs down the slope and eventually collects in channels or streams.

High runoff amounts are caused by heavy rains of short duration, which is a common feature of rainfalls in drylands. The risk for high runoff rates increases if soils are affected by erosion and surface crusting. Dryland soils often have a low water holding capacity, due to coarse texture and low content of organic matter (FAO, 1986). This increases the drainage losses and decreases the capacity to store water during and in-between growing seasons. A large number of soil and water management practices used to prevent uncontrolled surface runoff and thereby increase soil water content. Capturing runoff through water harvesting has widely been put forward as a way of controlling and protecting against deficiency in available plant water content in dryland farming systems.

The lower the infiltration rate of a soil, the more runoff will take place. Runoff is closely related to erosion and sediment transport. Erosion is the process by which soil particles are detached and carried away by wind and water. Soil erosion by water is the most common form of land degradation, and is often caused by human activities. Erosion depletes soil productivity and destroys land. Different kinds of soil and water conservation structures such as terraces and contour systems are effective in preventing runoff and erosion.



**Severely eroded land**

## **EXPERIMENT – MAXIMIZE SOIL COVER TO REDUCE RUNOFF AND EROSION<sup>1</sup>**

This experiment will demonstrate the influence of soil cover on increasing rainwater infiltration and reducing runoff and erosion.

**Time required:** 1 hour

**Materials:** Two wooden boxes; 30 cm wide, 40 cm long and 10 cm high with one end 2 cm lower than the other to provide an outlet over which the runoff can flow. Enough air-dry soil to fill two boxes to 8 cm depth, a 5 litre watering can and chopped crop residues to cover 1 box completely.

### **Procedure:**

1. Construct 3 open wooden boxes of the above dimensions.
2. 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 sill.
3. Add a layer of chopped crop residue of about 0.5 cm thickness over the soil surface in one box.
4. Place the boxes at an angle of about 25% with the lower sill of the boxes in the downhill direction and place a bowl beneath each water outlet.
5. Simulate a heavy rainstorm by holding the watering can about 2 meters above the first box and sprinkle a complete can of water over the box as uniformly as possible.
6. Record the amount and the colour of the runoff water that accumulates in the bowl.
7. As soon as the runoff has ceased, excavate the soil at the downhill end of the box, and note the depth to which water has penetrated.

### **Questions to discuss:**

- What changes have occurred to the soil surface and the surface pores?
- In which soil did more water infiltrate, and why?
- What are the advantages of soil cover for crops?
- What evidence is there of erosion?
- How does erosion affect the fertility of the soil?

<sup>1</sup> Source: Guidelines and Reference material on Integrated Soil and Nutrient Management and Conservation for Farmer Field Schools, FAO, 2000

## **EXPERIMENT – CONTOUR BARRIERS TO REDUCE RUNOFF**

This experiment will demonstrate the influence of contour barriers to reduce runoff and demonstrate the necessity of conducting field operations parallel to the contour on sloping land.

**Time required:** 2 hours

**Materials:** sticks, watering can, gravel mixed with cut dried grass, source of water

### **Procedure:**

1. Select a field clear of vegetation and with a slope of about 10-15%.
2. Mark out 3 plots of 1m x 1m in size, with a distance of at least 1 m between them.
3. Remove stones, vegetation or crop residues from the plots and smoothen the soil surface with your hands to remove surface irregularities.
4. Prepare 5 cm wide strips of grass and gravel across the plots. The strips should be placed at 20 cm distance from each other. On one plot the strips should be located on the contour, on one plot parallel to the slope direction and on one plot on the diagonal.
5. Slowly pour 10 litres of water at the up-slope end of each plot.
6. Study the water flow on the three plots.

### **Questions to discuss:**

- What differences could you observe in the flow of water on the three plots?
- On which plot did more water infiltrate, and why?
- On which plot did erosion take place the most?
- How can you relate the result of the experiment to management practices on-farm?

## EVAPORATION

Evaporation is the term for soil-water transfer to the atmosphere. The air continuously absorbs moisture from the soil. That is why the soil surface dries out quicker than the underlying soil layers in a soil profile. Evaporation in the field can take place from plant canopies, from the soil surface or from free-water surfaces. When the soil is bare, big amounts of water can be lost by evaporation. Strong sun and winds increase evaporation. When growing annual field crops, the soil surface may remain largely bare throughout the period of tillage, planting, germination and early seedling growth, and such high evaporation might take place that soil moisture is lost to the extent that it affects the growth of the young plants during their most vulnerable stage. Quick drying of a seedbed can doom an entire crop from the start. In drylands where water is scarce it is important to try to minimise evaporation as much as possible. This can be done by appropriate soil moisture retention practices. Evaporation can be reduced by keeping the soil surface covered, either by planting a cover crop together with the main crop, or by covering the soil surface with mulch. Minimal tillage methods are also possible alternatives for reducing water losses through evaporation.

### EXPERIMENT – SOIL COVER TO REDUCE EVAPORATION

In this exercise you will be able to see how evaporation takes place, and discover the benefit of soil cover to reduce evaporation. The exercise should be carried out in the middle of a sunny and hot day.

**Time required:** 45 minutes, and 20 min 4 hours later

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

**Procedure:**

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

## **EXPERIMENT – MULCHING TO REDUCE EVAPORATION<sup>1</sup>**

In this experiment you will discover the importance of crop residues and mulch to reduce moisture losses through evaporation. The experiment should be carried out in the dry season, since it is important that it does not rain while the experiment is carried out.

**Time required:** 2 hours the first day, 1 hours 3 days later and 1 hour a week later

**Materials:** sticks, 20 litre bucket, mulch or crop residues to cover 1.5 m<sup>2</sup>

### **Procedure:**

1. Select a cultivated field on flat ground, without crops and with a convenient water source nearby. Mark out two plots of 1.5 x 1.5 meters, 5 m apart from each other.
2. Flatten the top-layer of the soil in the plots and remove stones, weeds or residues.
3. Gently apply 40 litres of water to each of the two plots.
4. Cover one of the plots with a 5 cm layer of mulch. Leave the other plot uncovered.
5. Return three days later and examine the soil moisture in the two plots. Try to disturb the soil surface as little as possible while checking the soil moisture and replace all mulch on the treated plot.
6. Return one week later, check the soil moisture in the two plots and make a final evaluation of the benefits of mulching

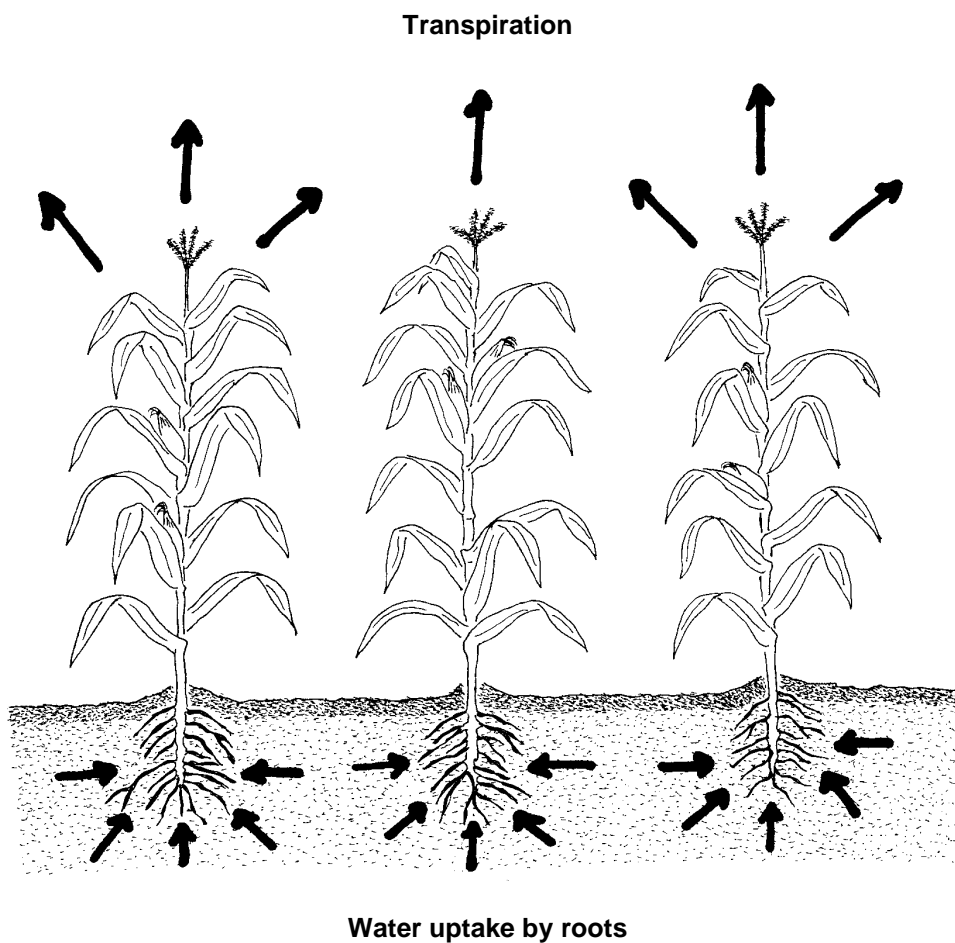
### **Questions to discuss:**

- What are the benefits of mulching?
- Is mulching a feasible option on your farm?
- Under what conditions is mulching useful?

<sup>1</sup> Adapted from: Guidelines and Reference material on Integrated Soil and Nutrient Management and Conservation for Farmer Field Schools, FAO, 2000

## WATER UPTAKE BY ROOTS

Nature can in some ways be wasteful, or at least it appears so from a human perspective. One of the best examples is the way that a plant requires big quantities of water from the soil, far more than is needed for plant growth. A thirsty atmosphere is continuously sucking moisture from the plant, forcing the plant to draw water from the soil through its roots. The process by which plants lose water vapour to the atmosphere is called *transpiration*. Since the plant also gets its nutrients through water uptake the transpiration rate is closely related to crop growth. The more water that passes through the plant, the faster will the plant grow. For a plant to grow successfully, it has to achieve a balance between water demands by the atmosphere and the available supply of water for the plant. The problem is that the demand by the atmosphere is more or less constant, while rainfall occurs only occasionally and often irregularly. To survive during dry spells between rains, the plant must rely on the reserves of water in the pores of the soil. When the plant does not have enough water supply in the soil it starts to release water from its tissues and the plant starts to wilt.



## **EXERCISE – CROP WATER REQUIREMENTS**

In this exercise you will discuss crop water requirements, and thereby gain an understanding of how much water different crops need and what affects the need of water by plants.

**Time required:** 45 minutes

**Materials:** paper, pens

### **Procedure:**

1. Divide yourself in groups of about 4-5 persons.
2. In each of the groups, compare the requirement of water for each of the crops grown in the area. Prepare a ranked list of all the crops with the most drought tolerant crops towards one end of the list and the crops that need most water to the other end.
3. In each group select 2-3 crops that you in detail analyse the water requirements for. Go through each growing stage of the crop and try to determine when water is important for the crop and when it is less crucial.
4. Discuss the physical factors that affect crop water requirement; soils, weather conditions etc.
5. Summarise the findings of your group and present it to the other groups.

## 5. SETTING UP ON-FARM TRIALS

### ON-FARM RESEARCH

Farmers are always forced to search for improvements of their farming, and to look for solutions to existing problems. This kind of testing by farmers has been a main activity which has stimulated development since mankind started cultivating land. Often farmers are used to experimentation with new management practices, although they may not call it a study, trial or on-farm research.

Unfortunately, during the last century, research has become institutionalized and most of the attention had been given to agricultural research carried out far from the farmers environment. New technologies have been developed without consulting farmers and testing of the technologies have taken place on-station. This has led to low adoption rates of improved technologies by farmers.

A small-scale farmer operating in a harsh environment can not afford to risk a crop failure by testing a new technology that he or she is not sure of what consequences it will have. A farmer often initially prefers to try out a new promising practice on a small scale, to enable an assessment to be made if its' profitability before using it on a larger scale. In principle the farmer is then conduction a simple on-farm test where the new practice is compared with the traditional practice. Based on the results of the test the farmer then decides whether to adopt the new technology or not.

In a village, you can usually find some farmers that keep experimenting on their own. These farmers keep testing different practices, and develop their own technologies which are well adapted to local situation. These technologies that have been developed by farmers are usually called innovations.

Both farmer innovators and traditional researcher have an important role to play in technology development. Researchers can help farmers in making sure that the testing is done systematically, and help in interpreting the results, while farmers can help researchers defining priority areas for research and adapt technologies to suit their particular needs. Participatory research differs from conventional research in that the object of the study, the farmers, actually take part in all aspects of the study of their own situation.

Farmer led on-farm trials are often done according to the following steps:

- selection of practices to be tested,
- decision on indicators to be monitored,
- decision on the scale of the test, number of replications etc.,
- selection of site,
- decision on design and layout of the test,
- decision on how to monitor the test,
- carrying out of the trial,
- evaluation of the trial.

## **EXERCISE – DISCUSSION: RESEARCH AND LOCAL INNOVATIONS IN YOUR AREA**

In this exercise you will discuss research and new technology development in your area. You will also identify local innovators, and try to determine which factors that affect adoption of new practices among farmers. By discussing these issues you will get ideas for what you want to achieve with your own on-farm research, and your confidence in testing and experimenting will be strengthened.

**Time required:** 1 hour

### **Topics for discussion:**

- Try to list all new technologies and new farming practices that you have encountered in your village, both technologies introduced by research and new practices developed by farmers. Compare to what extent these technologies have been adopted by farmers and the reasons for adoption.
- New practices formulated by researchers are mainly based on trials done on research stations or on on-farm plots under scientists' control. What implications does that have on the adoption of the technology by local farmers?
- What is the role of farmer to farmer exchange of information in your village?
- Discuss the relevance of following reasons for why technologies are adopted or not by smallholder farmers.
  - Variability of sites
  - Financial constraints
  - Skill requirement
  - Soil differences
  - Labour requirement
  - Input requirement
- Who are the innovators in your area? Try to identify the characteristics of a farmer who experiments on his own with new practices.

## **EXERCISE – PROMOTING FARMERS CONFIDENCE IN EXPERIMENTATION<sup>1</sup>**

In this exercise you will discover the advantages of sharing problems, and actively seek experience from others to find solutions. Further, your confidence in undertaking experimentation will increase.

**Time required:** 45 minutes

**Materials:** Five or six chairs arranged in a circle, the inside ones facing the outside, a watch, a bell and an object to make noise.

### **Procedure:**

1. Each participant should reflect on particular problems they will face or have faced. This can be focussed on a recent session and could include.
  - Problems in local technology development.
  - Problems and difficulties that you are likely to face when experimenting on your own farm.
2. Every participant should sit on any chair. The ones sitting in the outside will be the problem presenter and the inside ones will be the solution suggesters.
3. Each pair gets three minutes to discuss their problems and solutions.
4. After the three minutes the outside circle rotates by one chair bringing a new “client” to face each “consultant”.
5. Continue the same procedure until each “client” has been visited by each “consultant” posing the same problem each time.
6. All “clients” and “consultants” now write down a summary of the problems and solutions.
7. After this is done the “clients” and “consultants” change circles and reverse roles. The exercise is then repeated.
8. After the exercise is done, discuss what you learnt from the exercise.

### **Notes**

- If there are more than 10-12 participants, arrange to have several sets of chairs, and then carry out the exercise simultaneously in the different sets.

<sup>1</sup> Adapted from: Farmer Field School on Integrated Soil Management, Facilitator's manual, FARM Programme, 1998.

## SELECTION OF PRACTICES FOR TESTING

The first step in setting up on-farm trials is to decide what practice to experiment with. When experimenting in a group, there might be many main interests, and the members have to agree on what has highest priority. The group needs to identify problems and possible solutions and from there come up with related themes, which will form the base from which the group will select the trials to be conducted. The following exercises will help the group in identifying and prioritizing soil and water related problems and their possible solutions.

### EXERCISE – IDENTIFYING FARMING PROBLEMS AND CONSTRAINTS

In this exercise you will make use of the village map you constructed during a previous group session. New information will be added to the map and you will analyse the identified production constraints, in more detail.

**Time required:** 1 hour

**Materials:** cards, pens

**Procedure:**

1. Use the village map elaborated in a previous group session, to determine the soil and water conservation practices that are used in the village. List all the practices identified.
2. Discuss problems and constraints with each technology and try to determine the reasons and roots for the problems and constraints.
3. Form small groups (3 or 4 persons) and write down all the problems and constraints on cards.
4. Each group then presents their cards to the rest of the groups. Fix the cards on a board or a flip chart for all to see. Try to keep a discussion during the presentation.
5. After the presentations, cluster and regroup the problems and constraints according to major categories. Major categories could be related to the position of the farmers field on the slope, the slope of the field, soiltype, landuse, etc.
6. Name each cluster of problems and constraints.
7. Summarise the main findings of the exercise.

## EXERCISE – PROBLEM IDENTIFICATION THROUGH CALENDAR ANALYSIS

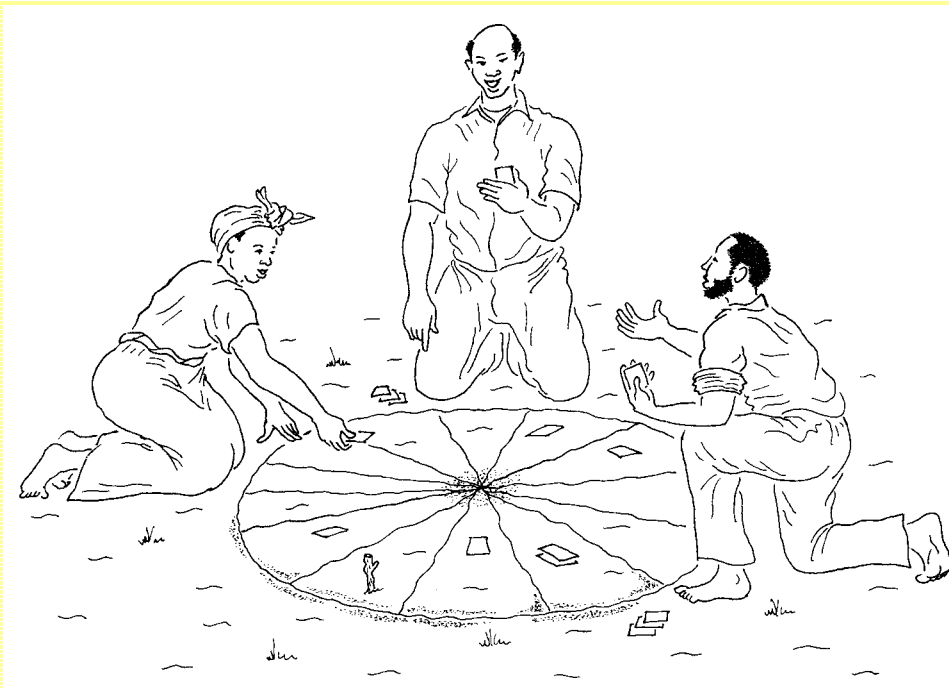
In this exercise you will analyse the farming year and identify problems and constraints encountered throughout the year. You will also try to identify the underlying cause of these problems.

**Time required:** 1 hour

**Materials:** cards, a stick, pens

### Procedure:

1. Draw a big circle (at least 2 meters in diameter) on the ground. Divide the circle into 12 sections, one for each month of the year.
2. Go through each month and discuss the farming problems and constraints that you usually encounter during that month. Write them down on cards and place the card in the respective month of the circle.
3. Discuss the cause of each of the problems and constraints (for example: If the problem is dry soil the reasons might be; to little rain, high runoff rates etc. Write down the causes on a new set of cards.
4. Wrap up and summarise the main points of the exercise.



## **EXERCISE – PROBLEM PRIORITIZATION THROUGH RANKING<sup>1</sup>**

In the previous exercises you identified the major problems and constraints in relation to soil and water management for crop production. Through this exercise you will be able to prioritise the problem and identify which problems are most relevant for your group. For this exercise guidance from a facilitator is recommended.

**Time required:** 1 hour

**Materials:** large sheets of paper, pens

### **Procedure:**

1. Write down on a large sheet of paper all the problems that were identified through previous exercises. If you can think of any additional problems, these should be added to the list.
2. Prepare a matrix on another sheet of paper, by writing all the problems across the top and down the left of the matrix.
3. To determine the priority of different problems, the problems should now be compared with one another through pair-wise ranking. The first problem listed on the left should be compared with all the problems listed on the top. Continue down the list until all problems have been prioritised.
4. Count the number of times that each problem was assessed as being most important.
5. Make a summary of the preferences and rank them according to priority on a new sheet of paper.

### **Questions to discuss:**

- Are there any problems missing on the list?
- Does the priority list correspond to what the group feel they would like to learn more about and experiment with?
- On what basis did you decide on the ranking of the problems?
- Are there problems on the list that are very closely related to one another?
- Do you agree with the final prioritisation list of the problems?
- Are all of the problems relevant to everybody in the group, or are different problems relevant to different farmers?

<sup>1</sup> Adapted from: Farmer Field School on Integrated Soil Management, Facilitator's manual, FARM Programme, 1998.

## EXERCISE – IDENTIFICATION OF POSSIBLE SOLUTIONS TO BE TESTED

In previous exercises soil and water related farming problems were identified and prioritised. Now possible solutions to these problems need to be identified. In this exercise the group will determine what practices currently are being used and what the benefits and requirements of these practices are. Since new practices and technologies might be available that are not known to the group yet, a facilitator with special knowledge on the topic is very useful during the process of identifying possible solutions. Farmers should also be able to combine the knowledge they have acquired through the training and their indigenous knowledge to identify new practices that can be tested as solutions. For any possible solutions a simple assessment of the resources needed and available (labour, cash, materials), should be carried out. This will make it possible to determine if the practice is suitable for local conditions.

**Time required:** 2 hour

**Materials:** large sheets of paper, pens

### Procedure:

1. Make a table on a large sheet of paper with the following columns, and list as many answers as you can think of in each category ;
  - main problems (the problems identified earlier)
  - physical conditions of the area (slope, soil type, climate etc.)
  - inputs/material available (cash, labour, stones, manure etc.)
2. Discuss one problem at a time, and try to identify a possible solution to the problem by considering the local conditions and inputs/materials available. Go through each problem until you have a list of possible technologies to test.

### Example:

Main problem	Physical conditions	Inputs/material available	Possible solutions
Soils have poor capacity to hold water and dry out quickly.	Shallow and sandy soils	Manure and dry plant materials	Making of compost to add to the soil for improved soil structure and water holding capacity.
Much soil moisture is lost through evaporation.	High temperatures and uneven distribution of rainfall.	Animal draft, cash for buying farm inputs.	No tillage or minimum tillage methods to conserve moisture in the soils.
Rainwater is lost through runoff and soils suffer from erosion	Gentle slopes	Stones and labour	Making stonelines along the contour to slow down runoff, and reduce erosion.

3. Look at your list of possible solutions and discuss following questions;
  - Have all main problems and possible solutions been included?
  - Are these solutions realistic in the present farmers' situation?
  - Which of these possible solutions would you like to test in the field?
  - What is needed to implement these solutions?

## **PLANNING ON-FARM TRIALS**

When possible solutions have been identified that the group would like to test in on-farm trials, the next step is to decide on “how” to do the testing. A suitable site needs to be selected, decisions have to be made on layout and design of the trials and a workplan has to be prepared, etc.

### **Decision on the need for replication**

The group has to decide how many trials to carry out in order to acquire enough information to evaluate the particular practice. Each possible solution should preferably be tested on several trials or by several farmers. If only 1 or 2 trials are conducted the results might be misleading if those trials; happened to be carried out on unrepresentative sites, are subject to pests or diseases, or are badly managed. With several trials it is also possible to assess the possible solution for a wide range of soils, crops and management conditions. As a general rule, the more replications the more reliable the results. However, often availability of resources, labor and sites make it difficult to carry out many replications, and farmers therefore might choose to only carry out one trial.

### **Selection of site**

The group has to decide on a place to carry out the trial. The ideal site for testing a practice will depend on the kind of trial that is to be conducted. It is important that the site selected represents the general conditions (soils, slope, fertility, management history, etc.) of the area. When choosing a field to locate the trials on it is important that the soil conditions are more or less the same over the whole field. If there are doubts of the homogeneity of the field it might be necessary to dig soil pits to check that the site of the trial is representative of the whole field. Try to avoid fields that are exceptionally stony, poor in nutrients, weedy or where crops never yield well. The site should further be protected from people or animals crossing the area, since these might damage the crops or structures on the plot. Also try to avoid locating the trials on the edges of a field.

### **Design and layout of the trial**

To see whether one has successfully tried out a new technique one needs to compare it to the usual practice. Without a comparison one does not know whether the new technology is better or worse than the old one. This is why a trial usually involves two plots – the “treated” plot (where the possible solution is tested) and the “control” plot (normal farming practice). In this way it is easy to compare the new technology with the usual practice. Where the possible solution involves several different treatments, the trial will have several “treated” plots and one “control” plot.

The “control” plot and the “treated” plot should be located side by side in the same field so that differences are easily seen, and soil conditions are as similar as possible.

The size of the field needed for the trial will depend on the number of treatments and the kind of practice that will be tested. For trials where the treatment involves adding organic matter or mulch, testing crop varieties or trials where rainwater is trapped by small structures, the plots can be fairly small (plots of 10 x 10 m are usually enough). For trials where the possible solution involves slowing down runoff or reducing

erosion the plots need to be larger (at least 20 m wide and as long (in the downhill direction) as the length of the field). This will enable the influence on slope length on the generation of runoff to be fully expressed. If fuel, labor or cost is to be evaluated the plot should be relatively large so that the practice can be implemented on a field scale. For tillage trials plots should be at least 50 m long (in the direction of tillage) and not less than 20 m wide.



## EXERCISE – WORKPLAN FOR FIELD TRIALS

In this exercise you will construct a workplan for the field trials. Before starting the trials, activities need to be scheduled and it has to be decided who is responsible for what. This workplan will serve as a guideline throughout the implementation of the trial.

**Time required:** 1 hour

**Materials:** large sheets of paper, markers

### Procedure:

1. In groups of about 4-5 persons brainstorm all the activities that should be undertaken to carry out the trial. If several trials are to be carried out, assign each group a different trial to brainstorm on.
2. Each group list the activities in chronological order on a large sheet of paper.
3. For each of the activities listed, decide on when the activity should be carried out, who is the responsible person and what materials/inputs that are needed. Write down all this information on the sheet of paper.
4. Present the workplan to the rest of the groups for discussion, comments and corrections.
5. Finalise the detailed workplan.



## **6. MONITORING AND EVALUATING ON-FARM TRIALS**

### **MAKING OBSERVATIONS AND MONITOR TRIALS**

In order to determine whether a new technology tested in an on-farm trial is better than the convention method it is important to monitor and observe differences between the two technologies. Without a comparison one does not know whether the new technology is better than the old one. Observing your trial helps you to identify the reasons why a certain technology performs well or not so well. If, for example, the maize on one plot grows faster or survives a dryspell better than the maize in another field it is important to observe and record these differences so that they are not forgotten and so that those observations can be referred to later during the final evaluation of the experiment. Monitoring also helps you to make sure that everything goes as close as possible to that was planned, that learning objectives are achieved and that field trials are being correctly implemented. The data collected is used to analyze, assess and draw conclusions from field tests activities involving the development and testing of farming technologies and practices. It is important that the data and information gathered are meaningful, simple, and of interest to all in the group.

Before the trial starts a plan should be made for how the plots are going to be monitored. You have to decide on which indicators to observe and how often to make the observations. The interval to make observations at depends on the kind of trial you are carrying out. If, for example, you are testing a technology that is said to improve soil moisture, it might not be necessary to observe the crops very often while the rains are frequent. However, if a dryspell occurs during the season it might be necessary to look at the crops more often in order to determine if the crops on the treated plot manage the dryspells better than the crop on the control plot.

It is important to be honest in one's judgement. Often one is in favor of one technology versus another. It is a good idea to do the observations as a group in order to reduce the risk for biased observations. The wide experience of a group will also help in observing as much as possible from the trial and farmers will learn from each other. Extension workers are important additions to the group since they might take notice of things that farmers don't. For effective monitoring and evaluation it is important that everybody is actively involved in the activities. To facilitate this small groups are necessary, where there is mutual trust between the individuals. A large group intimidates the less bold and make consensus more difficult.

Whether a technique proves to be a success or not, it is important to analyze the reasons behind the results of the trial. It might be good to continue the trial for another season or try the technique under different conditions in order to fully understand the benefits or drawbacks with the technology. The more observations you have done during the trial the easier the final analysis of the technology will be. If a technology fails, don't give up! Discuss with your extension officer why it failed and try to come up with ideas of how the technology can be modified and improved to suit your needs.

## SELECTING INDICATORS

An indicator is a measurement that allows one to track changes. Indicators to be monitored during an on-farm trial might include productivity, yields, improved soil characteristics, input requirements, levels of technology and whether tested solutions were able to solve farmers' problems. Indicators provide a standard against which one can measure, assess or show progress. The indicators selected for monitoring of a trial directly depend on the objective of the trial. For example, if the objective of the trial is to improve yield, the indicators should be linked to crop performance and yield. The actual selection of indicators depend on the kind of information the group desires and how they want to measure change. In some cases, suitable indicators might be difficult to find. It is important that the whole group is involved in the decisions about which indicators to monitor and that everybody understands exactly what will be monitored and how. This may require in-depth discussions with everybody in the group. Selecting good indicators requires experience and skill. It may be useful to seek help from an extension worker to select appropriate indicators.

Some examples of indicators used by farmer groups to measure change are shown below:

- Yield per hectare
- Number and size of fruit
- Plant height
- Color of leaves
- Number of leaves
- Number and size of maize cobs
- Survival rate of seedlings
- Days spent working on the trial
- Cost of labor
- Income from selling plot produce
- Temperature of the soil
- Signs of erosion
- Soil moisture
- Root penetration in the soil
- Soil resistance to penetration by a knife or stick

## **EXERCISE – SELECTION OF INDICATORS<sup>1</sup>**

In this exercise you will identify and produce a list of measurable indicators to be used to monitor on-farm testing. You will also determine how the data will be kept and presented.

**Time required:** 1 hours

**Materials:** large sheet of paper, colour pens

### **Procedure:**

1. In groups of about 3-4 persons, discuss and indicate/write that you feel should be measured during the field test (yield, labour requirements, crop health, soil moisture etc.) Brainstorm in the group and list all ideas that come to your mind.
2. Discuss in the groups for each measurement selected how you want to measure it. Write down which indicator that can be used to measure changes for each measure you selected (e.g. kg of production, height of plant, time spent working in the field etc.)
3. Select a representative from each group to present the results of your work. Fix the list of measurements and respective indicators on the wall so all can see.
4. Look at the indicators and identify the ones that are most valid, reliable, relevant, specific, cost effective, and timely. This will allow you to identify indicators that are most suitable and easy to measure.
5. Finalise the list of measurements and indicators that will be used during the on-farm testing. One or two indicators for each measurement should be sufficient.
6. Decide on when the first measurement should start, how often it should be done, how records will be kept, and how the information will be shared amongst the group.

### **Questions to discuss:**

- Are the indicators selected easy to measure?
- How often should they be measured?
- Which part of the field will be used as a test to compare the effects of the improved practice against present farming practices?

<sup>1</sup> Adapted from: FAO-RAP publication. PME

## KEEPING RECORDS

Farm records can be defined as written information detailing all activities on the farm over a specific period. By observing your crops and farming activities closely, and through detailed record keeping, you will build up your farming knowledge step by step. Instead of repeating mistakes year after year, you will be able to determine ways of improving you farming and your yields. Farming has become more complex, and nowadays more information is available to the farmer. No farmer, however good his memory is, can keep all details of his farming activities in the memory. For the records to be beneficial and used it is important to keep records simple, clear and neat, and to write records which are brief but provide all necessary information. The records should be written down as soon as the activity is done so no information is forgotten and lost. When carrying out farm trials, records of monitoring activities and trial results are crucial for the final evaluation of the trial.

An example<sup>1</sup> of a field operation record is shown below:

SEASON _____	Field area _____
Crop growth _____	Variety _____
Ploughing date _____	Planting date _____
Inputs _____	
Seed rate Kg/ha _____	
Fertilizer at planting: type _____	amount _____
Top-dressing: fertilizer _____	amount _____
Other treatments _____	
Pests _____	
Diseases _____	
Weeds _____	
Other treatments _____	
Output:	
Harvesting date _____	Method used _____
Yield/ha _____	
Remarks _____	
_____	

<sup>1</sup>Source: Secondary Agriculture Form 1, Kenya Institute of Education, 1999

## **EXERCISE – DISCUSSION ON WHY AND WHAT TO RECORD<sup>1</sup>**

This exercise starts with questioning concerning the profit you as farmers made last year. This allows you to share information about records you usually keep. The discussion allows you to decide whether you might find it useful to keep more records than you usually do.

**Time required:** 1-2 hours

**Materials:** examples of records kept by the farmer participants (Note: everybody should bring in examples of farm records) large sheet of paper, colour pens

### **Procedure:**

1. Arrange the group members in a circle for sharing.
2. Discuss how much profit you make on your farms. Here are some suggested guide questions:
  - Who made a good profit last year?
  - How did you know that you made a profit?
  - Do you keep any written records of what you spend, earned and of your profits? What kind of records do you keep?
  - How much money and time do you spend on production?
  - How do you calculate what you spend (e.g. by counting the money or by counting the kilos of seed, sacks of fertiliser and bottles of pesticides)?
  - How much did each of you get for your produce last year?
3. Discuss what profits might have been made if farmers had made different decisions about the amount of inputs you used.
4. Discuss what kind of information you will need to record in order to compare the profit that is gained from the use of an alternative practice in the test plot and the profit made from the farmers' unaltered plots. Make a list of all the information that the group wants to record.

<sup>1</sup> Adapted from: Farmer Field School on Integrated Soil Management, Facilitators Manual. FARM Programme 1998.

An example of a trial record sheet is shown below field operation record is shown below;

<b>Type of experiment</b> .....		
<b>When was the trial carried out?</b> .....		
<b>What were the conditions during the trial?</b>		
<i>Soil type</i>		
<i>Climate</i>		
<i>Rainfall</i>		
<i>Slope</i>		
<i>Pests</i>		
<b>How was the trial set up?</b>		
<i>Description of trial design</i>		
<i>Plot size</i>		
<i>Crop planted</i>		
<i>Management practices</i>		
<i>Planting time</i>		
<i>Spacing</i>		
<b>What differences did you observe?</b>		
<i>Differences</i>	<i>New technology</i>	<i>Usual practice</i>
Plant growth		
Flowering and maturing (early/late)?		
Weed growth		
Drought tolerance		
Soil erosion (rills/sheet erosion)		
Total yields		
Labor requirement		
<b>What lessons have you learned from your experiment?</b>		
	<i>New technology</i>	<i>Usual Practice</i>
Advantages		
Disadvantages		
Ideas for modifications and improvements		

## 7. SOME SEASON LONG TRIALS

Below are some examples of season long trials that can be carried out as on-farm trials. The trials are intended to serve as a base for ideas on how to carry out trials on specific technologies. The trials included in this section can be modified according to the preference of the group.

### **FARM TRIAL 1 – STONE LINES TO REDUCE RUNOFF AND INCREASE INFILTRATION**

In this trial you will test stone lines as an option for slowing down runoff and increasing soil moisture on sloping lands.

**Materials:** Implements for land preparation and cultivation, supply of seed, fertiliser or manure, an A-frame (see annex III), notebooks and pieces of string.

**Procedure:**

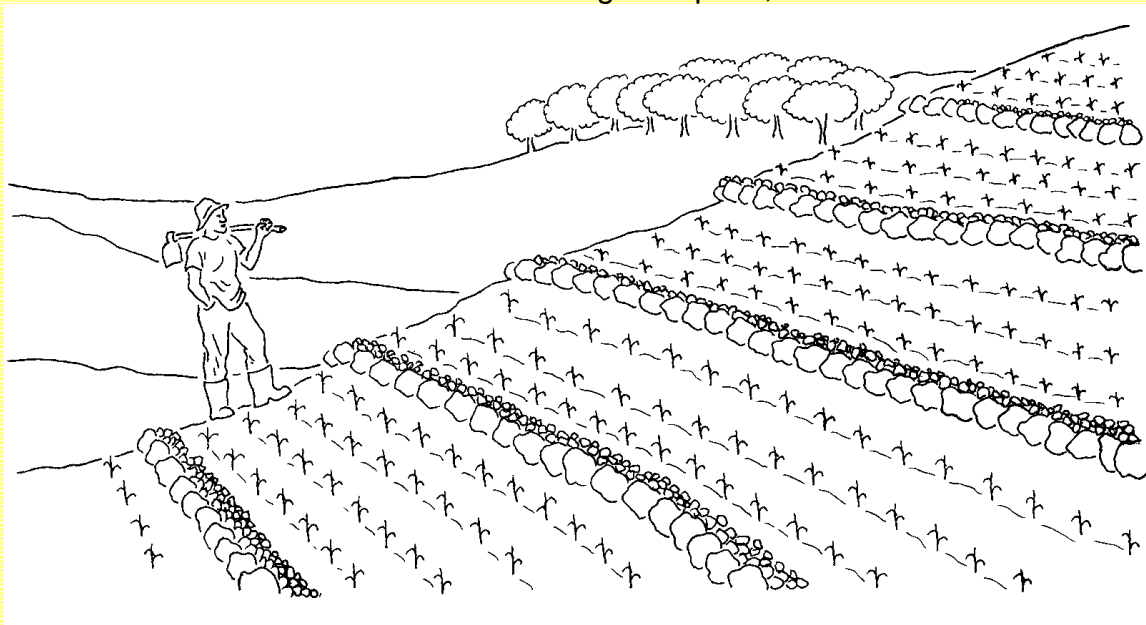
1. Select a field with a gentle slope on land where problems with runoff and erosion are known to occur.
2. Before the rainy season starts mark out two plots parallel to each other and parallel to the direction of the slope. The width of the plots should be at least 30 meters and the length at least 60 meters.
3. Use the A-frame to determine the contour lines in the treated plot. Mark the lines by placing sticks at the sides of the plot and draw a piece of string between the sticks.
4. Build stone lines along the contour lines in the treated plot. The stone lines should be about 40 cm wide and 30 cm high. Place bigger stones on the downhill side of the lines and smaller stones on the uphill side (see drawing below).
5. Cultivate, sow and manage the plots according to normal farming practice.
6. At regular intervals during the season monitor the following indicators on the two plots.
  - rills and signs of erosion
  - deposits of soil sediments, especially at the upslope side of the stone lines
  - soil moisture (feel the wetness of the soil)
  - crop performance

10. Harvest the crops from the two plots separately and record the yield

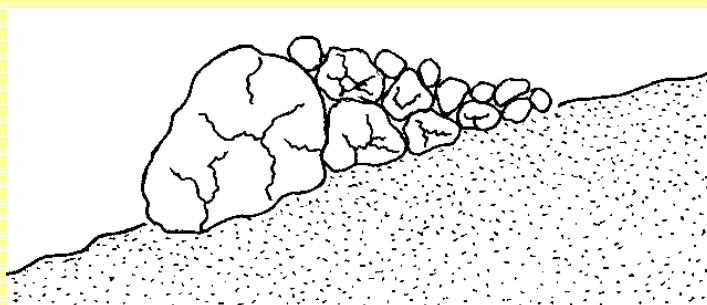
11. Make a final evaluation of the advantages and disadvantages of stone lines.

**Questions to discuss:**

- Was there a yield difference between the control and treated plot? Why?
- How do the stone lines prevent runoff and erosion?
- Are stone lines a feasible option on your farm?
- What other materials than stones, could be used in the same way as stone lines to reduce runoff?
- On what kind of land are stone lines a good option, and where is it not?



**Stone lines along the contour**



**Larger stones are placed downhill and smaller stones uphill**

## **FARM TRIAL 2 – CONTOUR GRASS STRIPS TO REDUCE RUNOFF AND INCREASE INFILTRATION**

In this trial you will test grass strips as an option for slowing down runoff, increasing soil moisture and reduce soil losses on sloping lands. A grass strip is a narrow band of grass planted on crop land along the contour.

**Materials:** Implements for land preparation and cultivation, supply of grass seed, fertiliser or manure, an A-frame (see annex III), notebooks and pieces of string.

### **Procedure:**

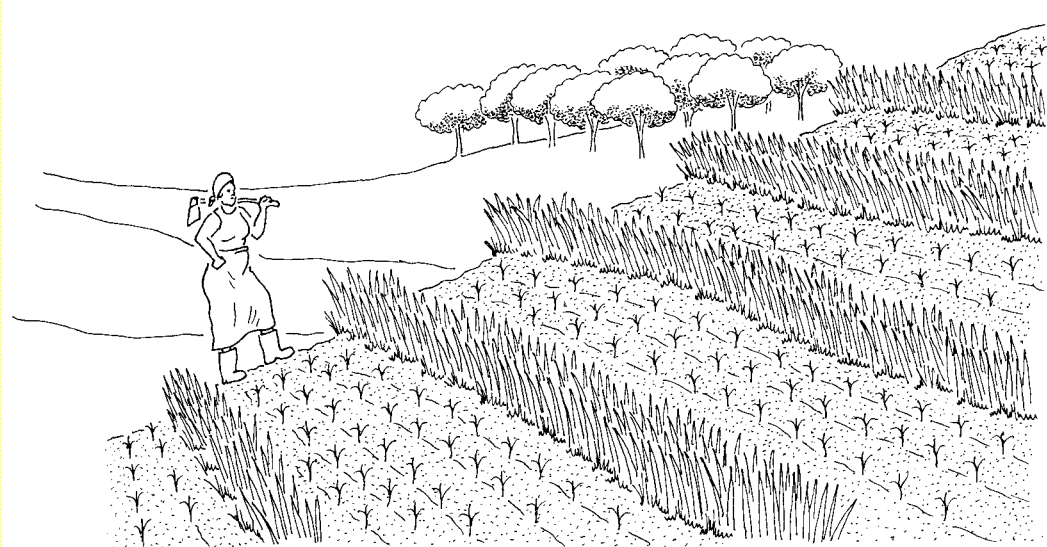
1. Select a field with a slope (not steeper than 10%), on land where problems with runoff and erosion are known to occur.
2. Before the rainy season starts mark out two plots parallel to each other and parallel to the direction of the slope. The width of the plots should be at least 20 meters and the length at least 60 meters.
3. Decide on a grass to be planted on the grass strips. Follow local recommendations! (Examples of grasses that can be used are Napier, Guinea and Guatemala grass).
4. Use the A-frame to determine the contour lines in the treated plot. Mark the lines by placing sticks at the sides of the plot and draw a piece of string between the sticks. Space the contour lines at about 10-20 m distance. The steeper land the narrower distance between the contour lines.
5. Plant the selected grass at each contour line on the treated plot. The grass strip should be about 0.5 – 1m wide. Follow local recommendations for spacing of plants within the strips.
6. Sow the whole field with the annual crop and apply the usual management practices throughout two seasons.
7. Weed the grass strips regularly until the grass strip has been reasonably well established.
8. During the second season, when the grass strips are well established monitor the following indicators;
  - signs of erosion
  - deposition of soil sediments above the grass strips
  - crop performance

9. Harvest the crop from the two plots separately each season and record yields.

10. Continue monitor the plots for a 3<sup>rd</sup> season in order to validate the trial result.

**Questions to discuss:**

- Was there a yield difference between the control and treated plot? if there was one, discuss the reasons for it?
- What are the advantages, disadvantages of establishment of permanent grass strips?
- Did the grass strips reduce runoff and erosion on the plot?
- Under what conditions are grass strips suitable?
- Discuss the choice of grass! Are there other grasses that might have given better results?



**Grass strips along the contour**

### **FARM TRIAL 3 – CONTOUR FURROWS TO TRAP RAINWATER**

In this trial you will test contour furrows as an option for trapping rainwater and increasing soil moisture on sloping lands. Contour furrows are shallow furrows following the direction of the contour and with soil ridged downhill. Rainwater will be stored in the furrows and will infiltrate into the soil instead of running down the field.

**Materials:** Implements for land preparation and cultivation, supply of seed, fertiliser or manure, an A-frame (see annex III) and pieces of string.

#### **Procedure:**

1. Select a field with a gentle slope (less than 20%) on land where problems with runoff and erosion are known to occur.
2. Before the rainy season starts mark out two plots parallel to each other and parallel to the direction of the slope. The width of the plots should be at least 30 meters and the length at least 40 meters.
3. Use the A-frame to determine the contour lines in the treated plot. Mark the lines by placing pegs at the sides of the plot and draw a piece of string between the pegs.
4. Till the land according to normal farming practice. Prepare the contour furrows on the treated plot. The furrows should be prepared by digging furrows along the contour line with a spacing of 1 m. The soil is ridged downhill. The depth of the furrow should be about 0.1 m and the height of the ridge should be 0.15 m.
5. Plant the control plot with maize according to normal farming practice. Planting on the treated plot is done on the upper side of the ridge.
6. Manage the plots according to normal farming practice.
7. At regular intervals during the season monitor the following indicators on the two plots.
  - rills and signs of erosion
  - soil moisture (feel the wetness of the soil)
  - crop performance
8. Harvest the crops from the two plots separately and record the yield
9. Make a final evaluation of the advantages and disadvantages of contour furrows.

## **FARM TRIAL 4 – PLANTING PITS FOR TRAPPING RAINWATER**

In this trial you will test planting pits for trapping rainwater and increasing soil moisture.

**Materials:** Implements for land preparation and cultivation, supply of maize seed, manure, and notebooks.

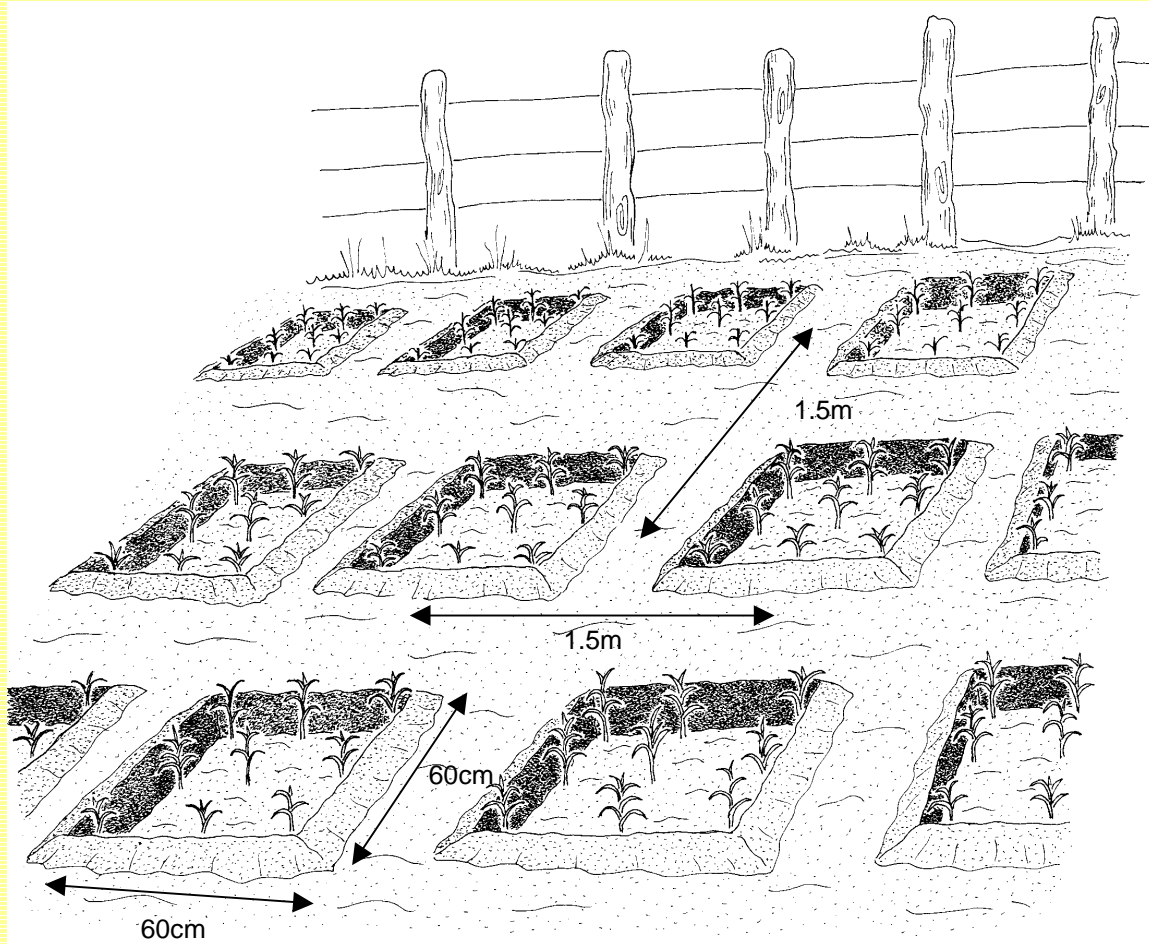
### **Procedure:**

1. Select a field where problems of restricted water availability are known to occur. The land should have a gentle slope and the soil should be representative of the soils in the area.
2. Select and mark out with stakes two similar plots – treated and control plots, of not less than 10 m x 10 m each. The plots should be representative of the whole field in terms of soil characteristics, cropping and management history.
3. Dig planting pits on the treated plot during the dry season before the rains start. The planting pits should be prepared as square pits, 60 x 60 cm wide and 20 cm deep. The distance between the centres of the pits should be 1.5 m (see figure below).
4. Spread a thin layer of manure mixed with a little bit of soil in the pit.
5. Plant the two plots with maize. The control plot should be planted according to normal farming practice. In the treated plot 9 seeds should be planted in each planting pit, 8 seeds along the sides and in the corners of the pit and 1 in the middle (see figure below).
6. At regular intervals during the season, monitor the crop performance on the two plots with regard to crop growth, soil moisture and signs of erosion.
7. Harvest the two fields separately and record the yields.
8. Make a final evaluation of the advantages and disadvantages of planting pits.
9. Assess the labour requirement of preparing the pits in 10 X 10 m plots.

### **Questions to discuss:**

- Was there a yield difference between the control and treated plot? Why?
- What were the advantages and disadvantages with planting pits?
- Do the planting pits conserve moisture?
- Are planting pits a feasible option on your farm?

- On what kind of land do you think planting pits are a good option?
- How can planting pits be modified to increase the benefits and to suit other crops?



**Spacing and size of planting pits**

## **FARM TRIAL 5 – SEMI-CIRCULAR BUNDS FOR FRUIT PRODUCTION**

Semi-circular bunds are earth bunds in the shape of semi-circles with the tips of the bunds on the contour, used for trapping rain water and increasing water infiltration. In this trial you will test semi-circular bunds for fruit production.

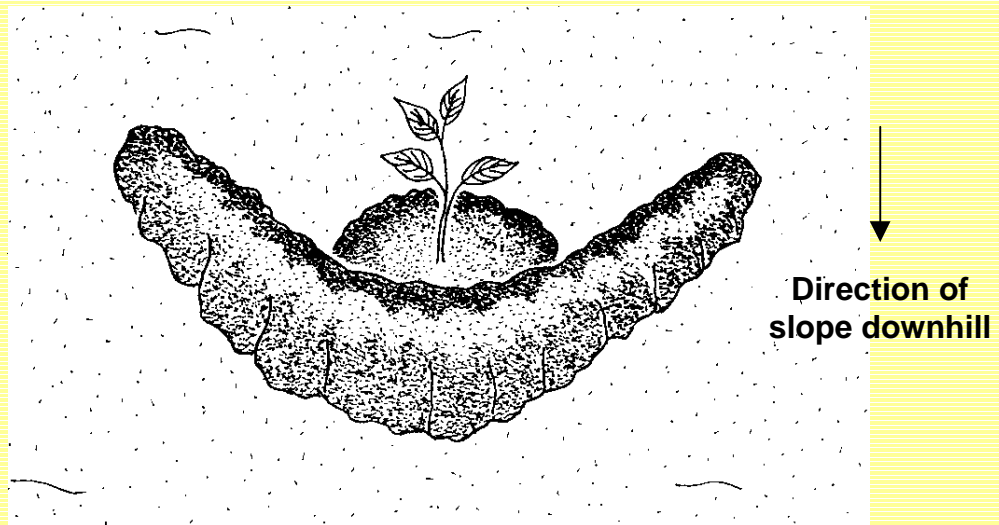
**Materials:** Tools for land preparation and cultivation, supply of fruit seedlings, manure, A-frame (see annex III), measuring tape, pegs, string and notebooks.

### **Procedure:**

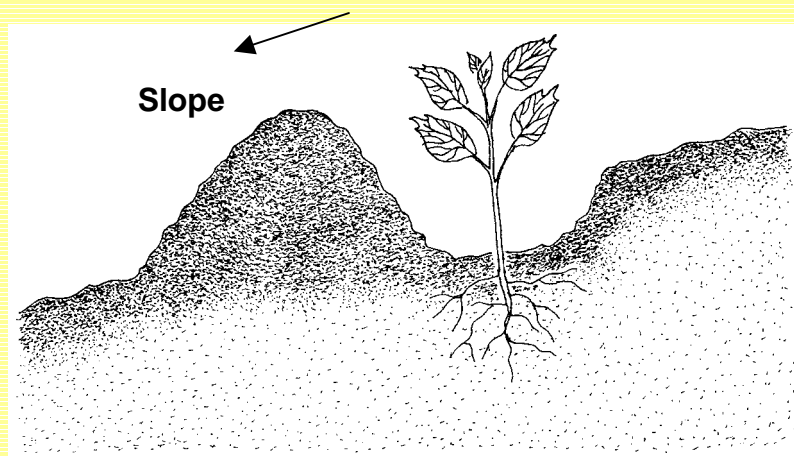
1. Select a field with a gentle slope on even terrain. The field should have deep soils (1, 5 m and deeper) in order for the root of trees to develop well.
2. Select and mark out with stakes two similar plots – treated and control plots, not less than 15 m x 15 m each.
3. Decide which tree crop to plant. Select a fruit crop that is known to do poorly in the area and which usually suffers from moisture stress.
4. Use an A-frame to determine the contour lines in the treated plot. Mark the lines by placing sticks at the sides of the plot and draw a piece of string between the sticks.
5. Before the rainy season starts, prepare the semi-circular bunds in the treated plot. The tip of the bunds should be placed on the contour line and have a height of about 25 cm. If stones are available they can be placed along the bund to strengthen it.
6. Make a small planting hole at the lower end of the semi-circular bund (see drawing below) and spread a thin layer of manure in the hole.
7. At the start of the rainy season, plant the fruit seedlings in the planting holes in the treated plot. Plant the same amount of fruit seedlings in the control plot, with the same distance between the seedlings, and according to normal farming practice.
8. At regular intervals during the season monitor the following indicators; survival rate of the seedlings, growth rate and performance of the fruit trees.
9. At harvest, compare the yield from the treated plot with the yield from the control plot.
10. Make a final evaluation of the advantages and disadvantages of semi-circular bunds.

**Questions to discuss:**

- Was there a yield difference between the control and treated plot? Why?
- What were the advantages and disadvantages with semi-circular bunds?
- Do the semi-circular bunds conserve moisture?
- How can the semi-circular bunds be modified to suit other crops?



**A semi-circular bund with a fruit seedling planted.**



**The bund is located downhill and the fruit seedling planted on the upper side of the bund.**

## **FARM TRIAL 6 – MULCHING FOR REDUCED EVAPORATION AND INCREASED SOIL FERTILITY**

In this trial you will discover the benefits of mulching when growing vegetables. Mulch is dry plant material used to cover the soil. It helps reduce evaporation and retain moisture, reduce soil erosion, and provide plant nutrients as the material decomposes.

**Materials:** Tools for land preparation, supply of seed, fertiliser or manure and mulch (dry plant materials such as grass, leaves or maize stalks).

### **Procedure:**

1. Select a flat piece of land that is known to be fairly fertile and suitable for vegetables.
2. Mark out two plots on the field with the dimensions of 10 x 10 meters. Decide which of the plots will be the control plot and which will be the treated plot.
3. Decide which vegetable will be grown on the plots. Preferably a vegetable that is known to be sensitive to moisture stress but not affected much by diseases should be chosen.
4. Put a layer (about 10 cm) of mulch on the treated plot. Make sure that the plant materials used as mulch are totally dry. Spread it over the soil using your hands or a rake.
5. On the treated plot make openings in the mulch cover where seeds are to be planted. Plant the two fields with the selected vegetable crop according to normal farming practice.
6. As the plants grow, try to keep the soil covered with mulch in the treated plot, but make sure that the plants are not buried or shaded out by the mulch.
7. If watering of the plant is necessary, apply the same amount of water on the two plots.
8. At regular intervals, monitor the performance of the crops and soil moisture availability (feel the soil wetness with your hands).
9. Record all harvests from the two plots.
10. Evaluate the results of the experiments and make a final evaluation of the benefits and limitations with mulching of vegetables.

## **FARM TRIAL 7 – ZERO TILLAGE AND CROP RESIDUES TO INCREASE SOIL MOISTURE<sup>1</sup>**

In this trial you will discover the benefits of zero tillage and crop residues to reduce erosion and increase soil moisture on sloping lands.

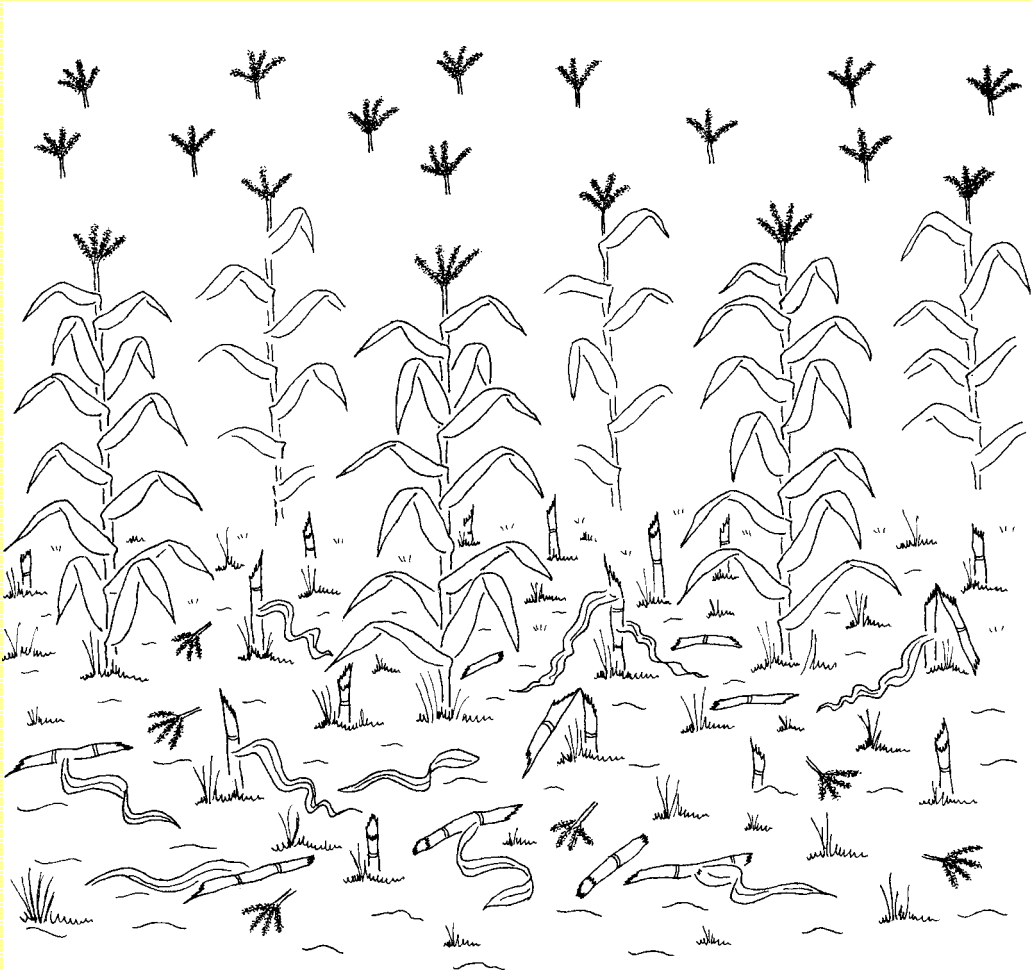
**Materials:** tools for land preparation, supply of seed, fertiliser or manure, herbicides, crop residue and notebooks

### **Procedure:**

1. Select a field of maize that is ready for harvest on gently sloping land. The soil should be typical of the area and, preferably, it should be a field that is known to be affected by erosion and runoff.
2. Mark out two plots on the field with the dimensions of 20 X 20 meters. The plots should be located parallel to each other and in the direction of the slope. Decide which one of the plots will be the control plot and which that will be the treated plot
3. Harvest all maize from the fields according to normal farming practice. Leave all crop residues on the treated plot. Cut the maize stalks into smaller pieces and make sure that the residues are well distributed over the plot.
4. Prepare the control plot according to normal land preparation practice. Leave the treated plot undisturbed and apply a pre-sowing herbicide to control weeds.
5. Sow both of the plots with beans or pigeon peas.
6. Follow normal farming practice for weeding, fertiliser/manure application, pesticide application and so on, on both plots.
7. At regular intervals throughout the season compare and evaluate crop performance in the two plots. Take notes of any differences or similarities between the plots. Use the following indicators for the evaluations:
  - crop appearance (colour, wilting, height, number of leaves)
  - runoff and soil erosion (rills, exposed roots)
  - soil moisture (feel the wetness of the soil)
  - weed presence
8. Harvest the two plots separately and record the yields.
9. Evaluate the results of the experiments and make a final comparison of zero tillage farming and conventional farming.

### Questions to discuss:

- If there was a difference in yield, what do you think the reason was?
- Were there bigger differences between the plots when it had not rained for a while than when it rained continuously?
- What were the differences in labour requirement?
- What are the advantages and disadvantages with zero tillage?
- Is zero tillage a feasible option on your farm?



<sup>1</sup> Adapted from: Guidelines and Reference material on Integrated Soil and Nutrient Management and Conservation for Farmer Field Schools, FAO, 2000

## **FARM TRIAL 8 – MINIMUM TILLAGE AND DEEP CULTIVATION FOR GREATER SOIL WATER AVAILABILITY<sup>1</sup>**

In this trial you will discover the benefits of minimum tillage and deep cultivation for increased water availability in the soil. The soil will not be turned over but cultivated with a subsoiler and ripper that break the hardpan, making it possible for roots to penetrate deeper into the soil.

**Materials:** tools for land preparation and weeding, sub-soiler, ripper, supply of seed, fertiliser or manure and herbicides.

### **Procedure:**

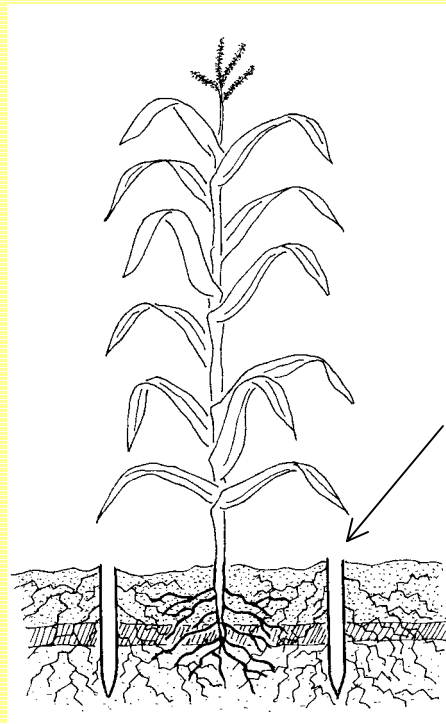
1. Select a field where problems with restricted water availability due to a compact subsoil layer, preventing root penetration, are known to occur. This usually occurs in soils with mixed texture, therefore not in sandy or clay soils.
2. Dig a soil pit in the field to confirm the presence of the hardpan and to further examine the root-restricting layer.
3. Decide which crop is to be sown in the field. It should be a crop that is sensitive to moisture stress.
4. Mark out two plots on the field – treated and control plot, with the dimensions of at least 50 X 20 meters. The plots should be representative of the whole field in terms of soil characteristics, cropping and management history.
5. Before the rainy season starts, plough the treated plot using a sub-soiler drawn by four oxen. Plough the land along the contour, leaving 1 meter between the rows. On steeper land leave 0.5 m between rows.
6. After the first rain, use a ripper on the treated plot to break up the soil and prepare furrows for planting.
7. Plant both the treated and control plot with the selected crop.
8. Weed both plots well and apply manure and herbicides as needed.
9. Monitor the following indicators regularly;
  - crop performance
  - soil moisture availability
  - presence of weeds
10. Harvest the two plots separately and record the yields.

12. After harvest dig a soil pit in each of the two plots and compare root penetration.

11. Evaluate the results of the experiments and make a final comparison between minimal tillage and conventional farming.

**Questions to discuss:**

- If there was a difference in yield, what do you think was the reason?
- Was there a bigger difference in crop performance between the plots when it had not rained for a while than when it rained continuously?
- What were the differences in labour requirement?
- What are the advantages and disadvantages with minimal tillage and deep cultivation?
- Is minimal tillage and deep cultivation a feasible option on your farm?



Crack created  
by a sub-soiler

**Ploughing with a subsoiler breaks the compacted soil and creates cracks, making it possible for roots to penetrate the plough pan.**

<sup>1</sup> Adapted from: Guidelines and Reference material on Integrated Soil and Nutrient Management and Conservation for Farmer Field Schools, FAO, 2000

# ANNEX I

## LIST OF TECHNICAL TERMS

**A-frame** – A wooden structure, used to determine contour lines (see annex III for diagram).

**Annual plant** – A plant that grows for only one season (or year) before dying, in contrast to a perennial, which grows for more than one season.

**Arid** – Very dry climate with less than 300 mm average annual rainfall, where cropping is possible only with support of water harvesting or irrigation.

**Bench terrace** – An embankment constructed across sloping fields with a steep drop on the downslope side.

**Bund** – A ridge of earth placed in a line to control water runoff and soil erosion.

**Crop residue** – The portion of a plant that is left in the field after harvest, e.g. maize stover.

**Contour** – An imaginary line joining all points of the same height on a land surface. A contour terrace is laid out on a slope at right angles to the direction of the slope and nearly level throughout its course. A contour ditch is sometimes constructed along the contour to store and conserve water.

**Cover crop** – A close to the ground growing crop grown for the purpose of protecting and improving soil between periods of regular crop production or between rows of crops.

**Drought** – The absence of rain for a period long enough to cause depletion of soil moisture and damage plants.

**Dry spell** – Shorter period of drought during the cropping season.

**Erosion** – The wearing away of the land surface, or detachment and movement of soil and rock by running water, wind, ice, or other geological agents, including gravitational creep.

**Fallow** – Land resting from cropping, which may be grazed or left unused, often colonized by natural vegetation.

**Fertilizer** – Any organic or inorganic material which is added to the soil to supply one or more plant nutrients.

**Fodder** – Parts of plants which are eaten by domestic animals. These may include leaves, stems, fruit, pods, flowers, pollen, or nectar.

**Hardpan** – Compressed layer of soil at a depth of about 15 cm, usually formed by continuous plowing on a field with a conventional plough.

**Humus** – Organic matter that has undergone decomposition.

**Hydrological cycle** – The circulation of water from the earth surface to the atmosphere and back again.

**Infiltration** – The process by which water enters the soil surface.

**Infiltration rate** – The maximum rate at which water can enter a soil under specific conditions.

**Intercropping** – Growing two or more crops in the same field at the same time in a mixture.

**Manuring** – Application of animal dung, compost or other organic material used to fertilize the soil.

**Minimum tillage** – Land preparation and tillage without turning the soil over.

**Monitoring** – The process by which a technology, activity or practice is observed regularly, over time.

**Mulch** – Dead plant material, such as dried grass, leaves straw and crop residues, often used to cover the ground with the objective of protecting the soil from impact of rainfall, controlling weeds or moisture loss and, in some cases, to fertilise the soil.

**Organic matter** – Material that originates from plants and animal remains, such as crop residues, leaves, roots and manure.

**Runoff** – The proportion of the rainfall on an area that does not enter the soil and is discharged from the area through stream channels.

**Semi-arid** – Fairly dry climate with average rainfall of about 300-700 mm, with high variability in rainfall.

**Soil erosion** – The process of which soil material is transported with wind and water.

**Soil evaporation** – The process by which soil lose water to the air, also sometime called soil breathing.

**Soil moisture (soil water)** – Water held in the soil and available to the plants through their root system, also called soil water.

**Soil structure** – The arrangement of soil particles to form lumps or clods of soil.

**Soil texture** - The size of the individual particles of the soil.

**Soil Profile** – Vertical arrangement of various soil layers or horizons.

**Stover** – The mature, cured stalks of maize or sorghum from which the grain has been removed.

**Surface sealing** – A thin, compact and dense layer on top of the soil, which greatly reduces the infiltration rate.

**Topography** – The physical description of land; changes in elevation due to hills, valleys and other features.

**Transpiration** – Active process by which plants absorb water from the soils and release it to the atmosphere, also sometimes called plant breathing.

**Zero tillage** – Planting without land preparation.

## ANNEX II

### REFERENCES

- Biamah, E. Rockström, J. and Okwach, G. 2000. Conservation Tillage for Dryland Farming. RELMA. Nairobi. Kenya
- Critchley, W. 1991. Looking after our land: Soil and Water Conservation in Dryland Africa. Oxfam. UK.
- CTA. 1997. Water harvesting and soilmoisture retention. Agrodok-series No.13. Agromisa, Wageningen, The Netherlands.
- FAO and IIRR. 1995. Resource management for upland areas in Southeast Asia. FARM Field Document 2. FAO, Bangkok, Thailand and IIRR, Cavite, Philippines.
- FAO. 1976. The soil
- FAO. 2000. Guidelines and Reference material on Integrated Soil and Nutrient Management and Conservation for Farmer Field Schools.
- FAO-IPM Secretariat. 1993. IPM Farmer Training: The Indonesian Case. Yogyakarta. Indonesia.
- FAO-RAP. 1988. Participatory Monitoring and Evaluation, Handbook for Training Field Workers.
- FARM Program. 1998. Farmer Field School on Integrated Soil Management, Facilitator's manual. Thailand
- Hillel, D. 1982. Introduction to soil physics. Academic press.
- Kenya Institute of Education. 1999. Secondary Agriculture Form 1. Nairobi.
- Rockström, J. and Falkenmark, M. 2000. Semiarid Crop production from a Hydrological Perspective: Gap between potential and Actual Yields. Critical reviews in Plant Sciences, 00(0):000-000 (2000).
- Thomas, D. B. (ed.). 1996. Soil and water conservation manual for Kenya. Soil and Water Conservation Branch, Ministry of Agriculture, Livestock Development and Marketing, Nairobi, Kenya.

## ANNEX III

### HOW TO DETERMINE CONTOUR LINES WITH AN A-FRAME<sup>1</sup>

An A-frame consists of three pieces of wood, fixed together in the shape of a capital letter “A”. The A-frame is held upright, and a weight on a string hangs down from the top of the “A” to act as a plumb-line. If the A-frame is on perfectly level ground, the string crosses the horizontal bar of the “A” at a certain point. This point is marked during calibration.

To use the A-frame it is “walked” across the slope, making sure that the two legs are level each time by checking if the string crosses the horizontal bar at the calibration point. If not, the forward leg is moved until the string shows the frame is level. The positions of the legs on the ground are marked with pegs, and then the frame is pivoted around to mark a new point on the slope.

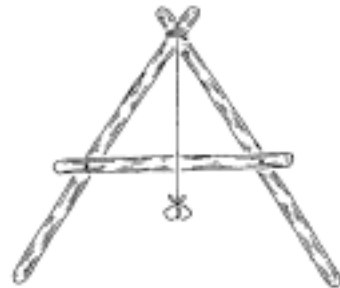
#### Requirements

- Two straight wooden poles that are about 2 m long
- One straight wooden pole that is about 1.5 m long
- A round stone
- Approximately 1.5 m of strong string

#### Preparing the A-frame

1. Use string or nails to make an frame in the shape of an “A”. Make sure that the two long poles are of exactly the same length.

2. Tie one end of the string to the top of the “A” and tie the other end tightly around a stone. Raise up the A-frame and make sure that the stone hangs about 15 cm below the cross pole.



#### Calibrating the A-frame

3. Stand the A-frame on reasonable level ground. Mark on the ground where the two legs stand.

4. Hold the A-frame still and make a mark lightly on the crossbar where the string crosses it.

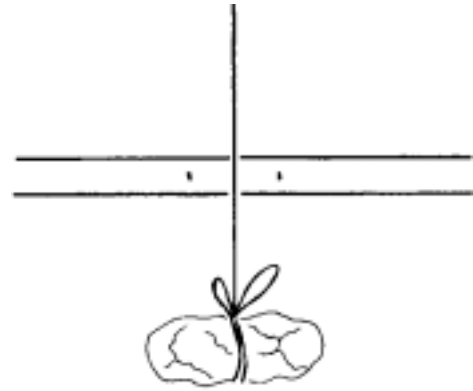
5. Turn the A-frame around, so that each leg stands exactly where the other had stood and make a second light



<sup>1</sup> Source: Sustainable Agriculture Manual, IIRR, 1998

mark on the crossbar where the string crosses it.

6. Make a heavy mark halfway between the two light marks. This is the point where the string would cross if the A-frame was standing on exactly level ground.



### Marking the contour

7. Go to the centre of the field that should be marked. Stand the A-frame up and mark where the first leg stands with a peg or large stone.

8. Hold this leg in place while slightly moving the other leg up and down the slope till the string crosses the crossbar exactly where the mark is.



9. Mark this point on the ground with a second peg or stone. The string should be very close to, but never touch the crossbar.

10. Continue in this manner to the end of the field.

11. The line of pegs or stones will mark a contour line, meaning that they will all be at the same height on the slope. The pegs are usually not in a straight line. If, necessary, make a smooth curve by moving them a little up and down.



12. To make another contour line, move up and down the slope a certain distance – usually about 20 m on a gentle slope.

13. The contour lines can then be used as a guideline for making terraces, grass strips, stone lines or ditches.

## ANNEX IV

### TILLAGE EQUIPMENT<sup>1</sup>

In the last few years conservation tillage equipment has become available to Kenyan smallholder farmers. This equipment has been developed in Zambia and Zimbabwe through years of applied research involving farming communities. Equipment for conservation tillage is shown and described below.

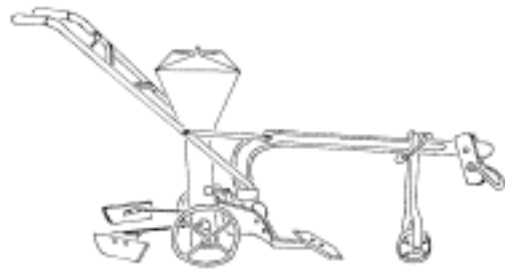
#### Magoye ripper attachment

This is used for making planting furrows (followed by planting by hand) in unploughed or ploughed fields. The attachment can be attached on a plough beam and works well in dry soils.



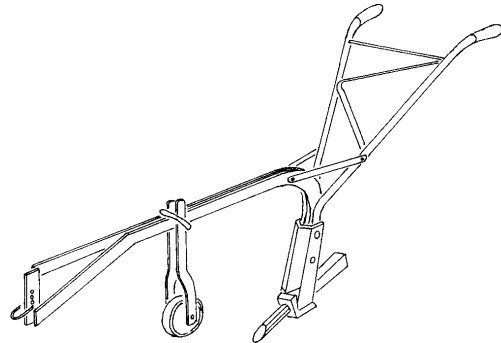
#### Ripper planter attachment

This is a ripper attachment to which an additional planter module is fitted. The planter can be used much earlier in the season than a conventional planter. Different crops can be planted by using different seed rolls.



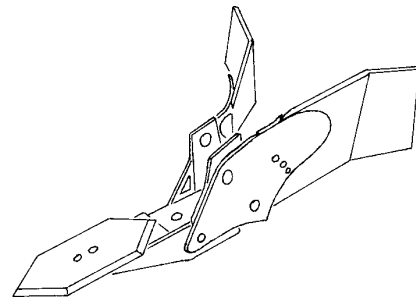
#### Sub-soiler attachment

This is for deep furrowing in compacted soils. The attachment needs a beam extension.



#### Ripper-ridger attachment

This is a Magoye ripper attachment to which a pair of adjustable wing extension blades and an optional rudder area used. Like any other ridger, it can be used for weeding and making and re-building ridges.



<sup>1</sup> Source: Conservation Tillage for Dryland farming, RELMA, 2000