

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



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

Compiled by:
Deborah Duveskog

Contributors:
Mbeere Farmer Field Schools
Daniel Nyagaka
Benjamin Mweri
Mwamzali Shiribwa
Dr. Pascal Kaumbutho



Ministry of Agriculture



Published by The farm Level Applied Research Methods for east and Southern Africa
GCP/RAF/334/SWE

Copyright: FARMESA, Harare, Zimbabwe 2003
Version 1.1, March 2003¹

Design and layout: Deborah Duveskog
Printing: Fotoform Ltd.
Illustrations: Raymond Musumba Wamukoya

You are free to reproduce and distribute widely any part of this, provided that you acknowledge the source and the purpose is not for profit or gain.

Available from: Ministry of Agriculture and Rural Development, Kenya
Directors Office
Kilimo Hse. Cathedral Rd.
P.O Box 30028
Nairobi, Kenya
Tel: +254-2-725723

FAO Representation, Kenya
Utumishi Co-op. Hse
Mamlaka Rd. Off Nyerere Rd.
P.O. Box 30470
Nairobi, Kenya
Tel: +254-2-725069 / 725359
E-mail: FAO-KEN@field.fao.org

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area of its authority, or concerning the delimitation of its frontier and boundaries.

¹ 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-Sahara 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.

P. ANANDAJAYASEKERAM
Team Leader and Methods Specialist
FARMESA

Dr. J. K. WANJAMA
Director of Agriculture,
Ministry of Agriculture and Rural Development

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 FARMESA² (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

² 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

CONTENTS

FOREWORD	iii
PREFACE	v
1. HOW TO USE THIS STUDY GUIDE	1
2. THE FARMER FIELD SCHOOL APPROACH	2
3. OVERVIEW OF WATER HARVESTING AND SOIL MOISTURE RETENTION APPROACHES	5
Retention ditches	7
Contour farming	9
Water harvesting by external catchments	9
Contour furrows	11
Stone lines	12
Grass strips	13
Planting pits	14
Semi-circular bunds	15
Earth basins	16
Mulching	17
Cover crops	18
Conservation tillage	19
4. BASIC SCIENCE OF SOIL AND WATER	21
The land in your village	21
<i>Exercise - Village land use map</i>	22
The soil profile	23
<i>Exercise - Soil pit</i>	25
Soil texture	27
<i>Exercise - What is soil made of?</i>	28
<i>Exercise - How to “feel” the soil texture</i>	29
Soil structure	30
<i>Exercise - Soil structure analysis</i>	32
Soil air	32
<i>Exercise - Finding out the amount of air in the soil</i>	33
Organic matter and humus	34
Water and farming	35
The circulation of water	35
<i>Exercise - The circulation of water, and rainfall patterns</i>	37
Infiltration of water	38
<i>Experiment – Comparison of water infiltration rates on different soils</i>	39
Water in the soil	40
<i>Experiment – Soil lump rise</i>	41
<i>Experiment – Soil tin test to determine the capacity of a soil to hold water</i>	42
<i>Experiment – Comparison of clay, sand and organic matter to retain water</i>	43
Runoff	44
<i>Experiment – Maximise soil cover to reduce runoff and erosion</i>	45
<i>Experiment – Contour barriers to reduce runoff</i>	46
Evaporation	47
<i>Experiment – Soil cover to reduce evaporation</i>	47
<i>Experiment - Mulching to reduce evaporation</i>	48
Water uptake by roots	49
<i>Exercise – Crop water requirements</i>	50

5. SETTING UP ON-FARM TRIALS	51
On-farm research	52
<i>Exercise - Discussion: Research and local innovations in your area</i>	52
<i>Exercise - Promoting farmers confidence in experimentation</i>	53
Selection of practices for testing	54
<i>Exercise - Identifying farming problems and constraints</i>	54
<i>Exercise - Problem identification through calendar analysis</i>	55
<i>Exercise - Problem prioritisation through ranking</i>	56
<i>Exercise - Identification of possible solutions to be tested</i>	57
Planning on-farm trial	58
<i>Exercise - Workplan for field trials</i>	60
 6. MONITORING AND EVALUATING ON-FARM TRIALS	 61
Making observations and monitor trials	61
Selecting indicators	62
<i>Exercise – selection of indicators</i>	63
Keeping records	64
<i>Exercise – Discussion on why and what to record</i>	65
 7. SOME SEASON LONG TRIALS	 67
Farmtrial 1 - Stone lines to reduce runoff and increase infiltration	67
Farmtrial 2 - Contour grass strips to reduce runoff and increase infiltration	69
Farmtrial 3 - Contour furrows to trap rainwater	71
Farmtrial 4 - Planting pits for trapping rainwater	72
Farmtrial 5 - Semi-circular bunds for fruit production	74
Farmtrial 6 - Mulching for reduced evaporation and increased soil fertility	76
Farmtrial 7 - Zero tillage and crop residues to increase soil moisture	77
Farmtrial 8 - Minimum tillage and deep cultivation for greater soil water availability	79
 ANNEXES	 81
Annex I - List of terms	81
Annex II - References	83
Annex III - How to make contour lines with an A-frame	84
Annex IV - Tillage equipment	86

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

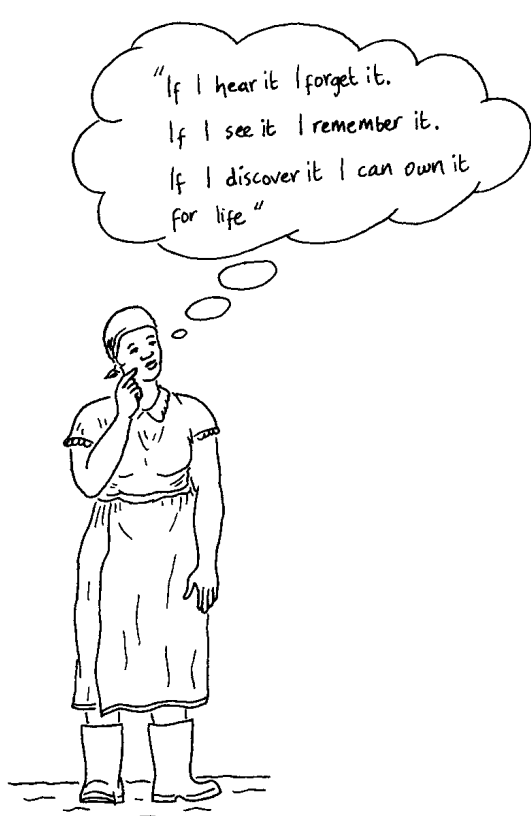
The Farmer Field School is described as a “School without walls”. It is a participatory method for technology development and dissemination, which gives the farmer an opportunity to make informed decisions about farming practices through discovery based learning. The field school usually involves 25-30 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 follows¹:

- **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.

¹ 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.

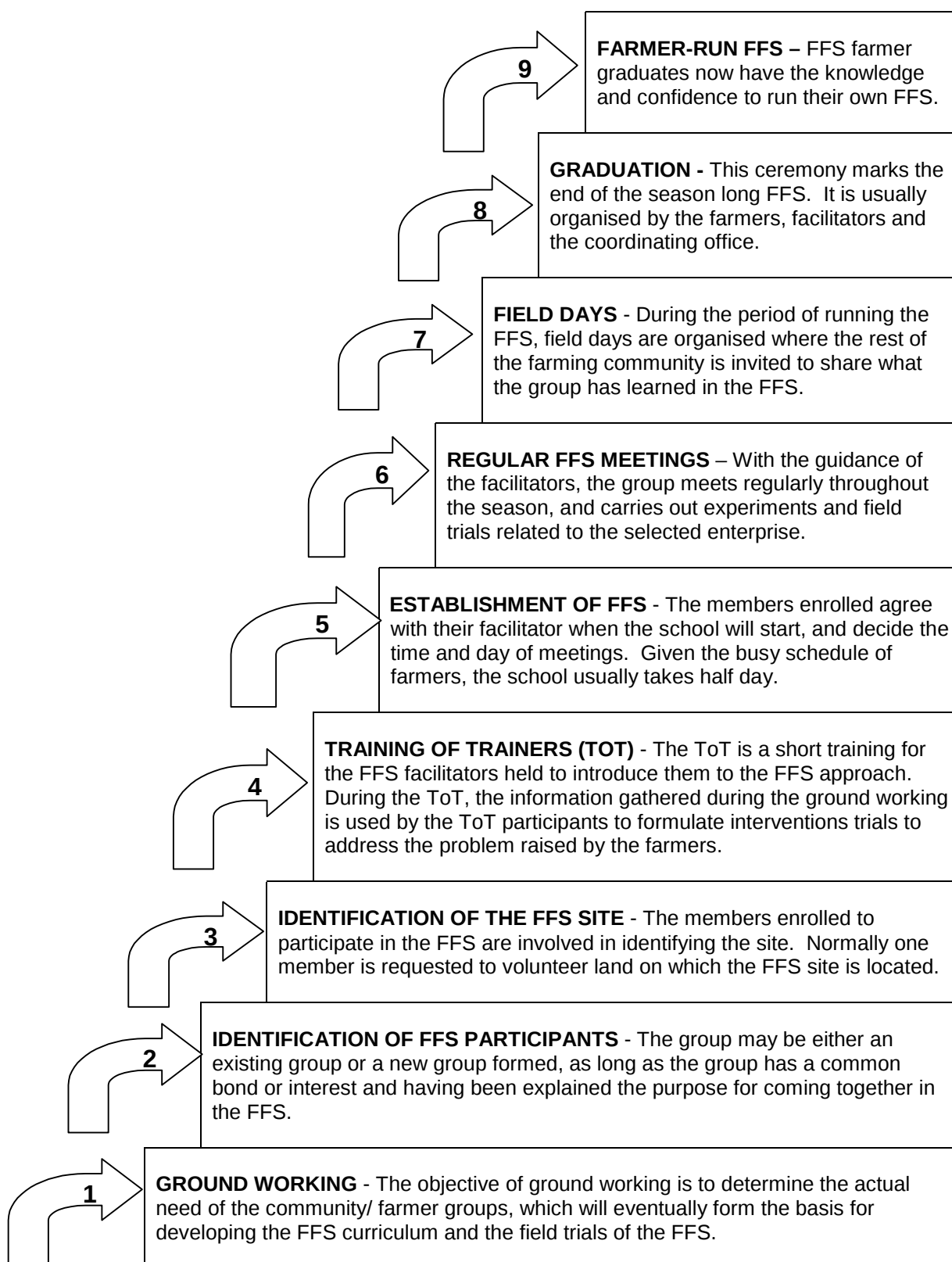


FARMERS ATTITUDE



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

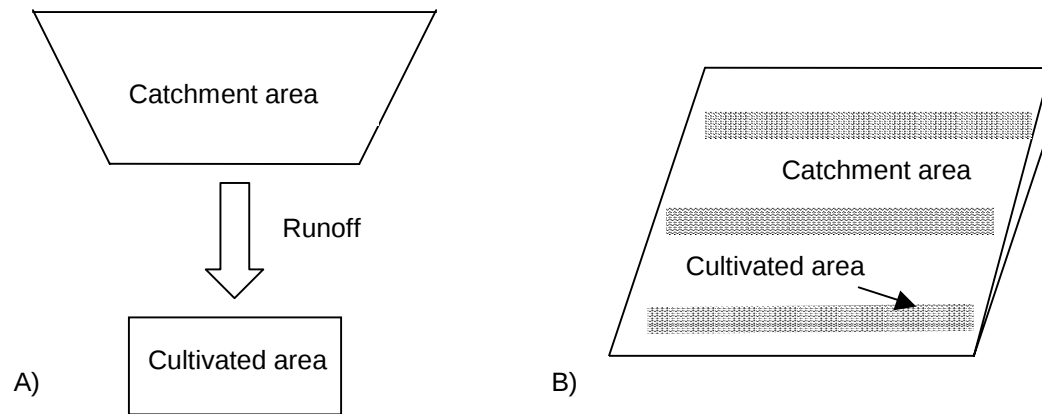
In Africa most of the food is produced by rainfed agriculture and the populations thereby depend directly on rainfall and agricultural productivity for their survival. Water is the most limiting factor for agricultural production in these regions and the low annual rainfall is often a major reason for 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

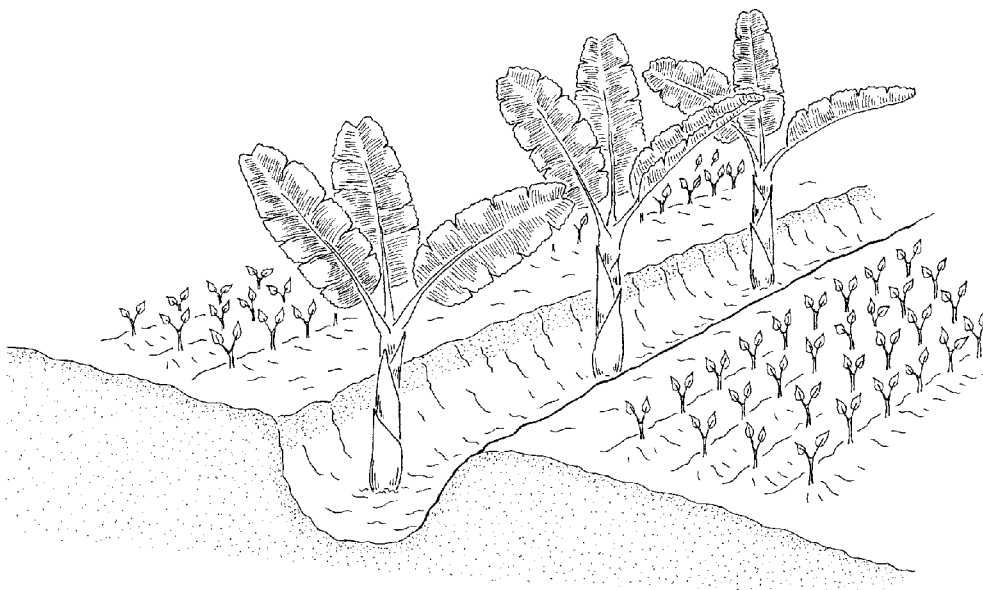
Retention ditches are particularly beneficial in semi-arid areas where lack of soil moisture is a problem. They should be constructed on flat or gentle sloping land and soils should be permeable, deep and stable. Retention ditches are not suitable on shallow soils or in areas prone to landslides.

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

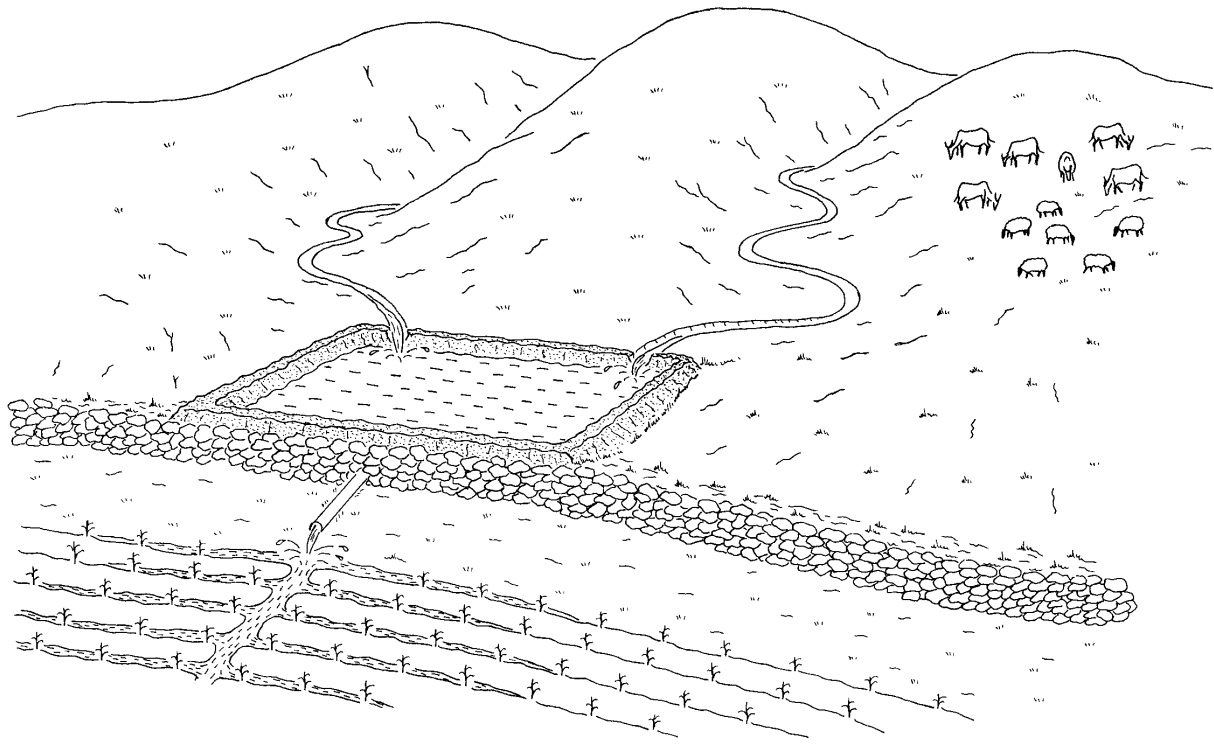
Water harvesting by external catchments is suitable in areas with low rainfall (300-800 mm per year) where there is a lot of uncultivated, open land available. It is not suitable in densely populated areas where most of the land is cultivated. Sites that are communally owned should be properly managed 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 dryspells.
- 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

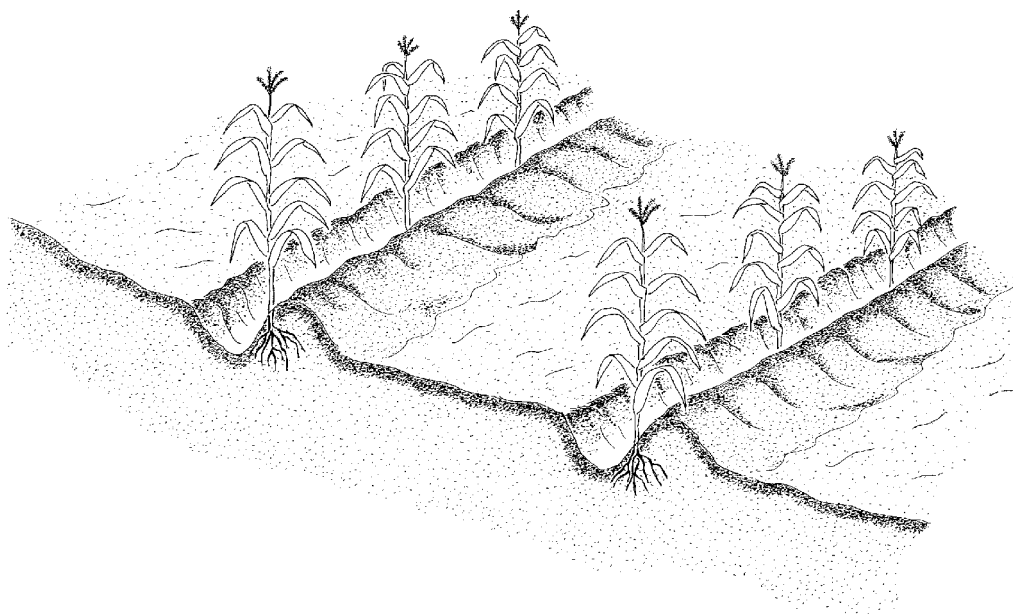
Contour furrows are suitable for areas with annual rainfall amounts of 350-700mm. The topography should be even to facilitate an even distribution of the water. Contour furrows are most suitable on gentle slopes of about 0.5-3%. Soils should be fairly light. On heavier, more clayey soils they are less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

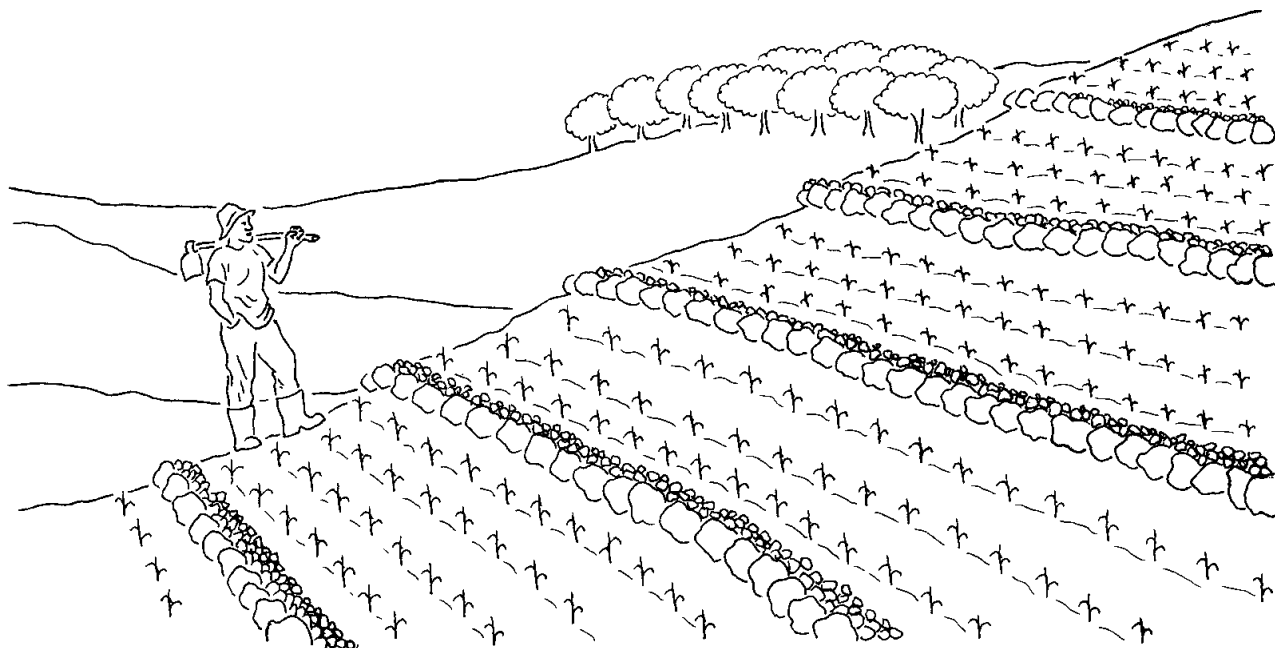
Stone lines are suitable on gentle slopes in areas with annual rainfall of 200-750 mm. They are often used to rehabilitate eroded and abandoned land. Plenty of stones should be locally available. Most agricultural soils are suitable.

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

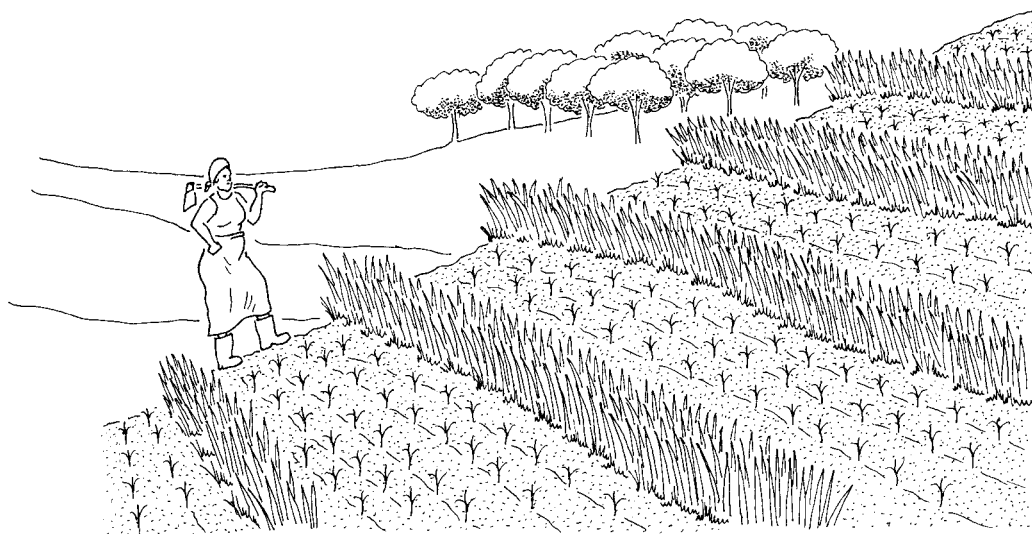
Grass strips are suitable in areas where there is a need of fodder or mulch. If farmers do not have livestock, they have little incentive to plant grasses. Grass strips are not applicable on steep slopes and in very dry areas since grasses might not withstand drought.

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

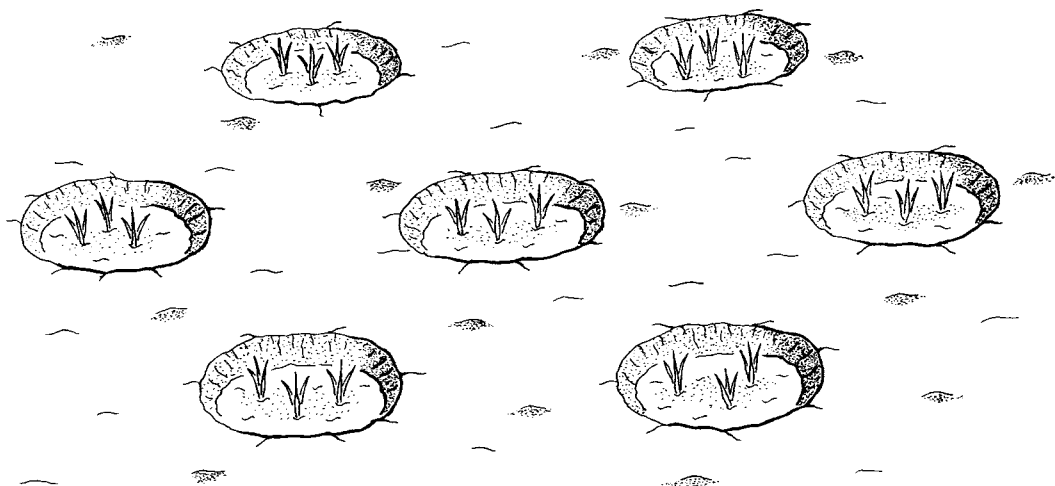
Planting pits have proven successful in areas with annual rainfall of 200-750 mm. They are particularly useful for rehabilitate barren, crusted soils and clay slopes, where infiltration is limited and tillage is difficult. The slope should be gentle (below 2%) and soils should be fairly deep. Where soils 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

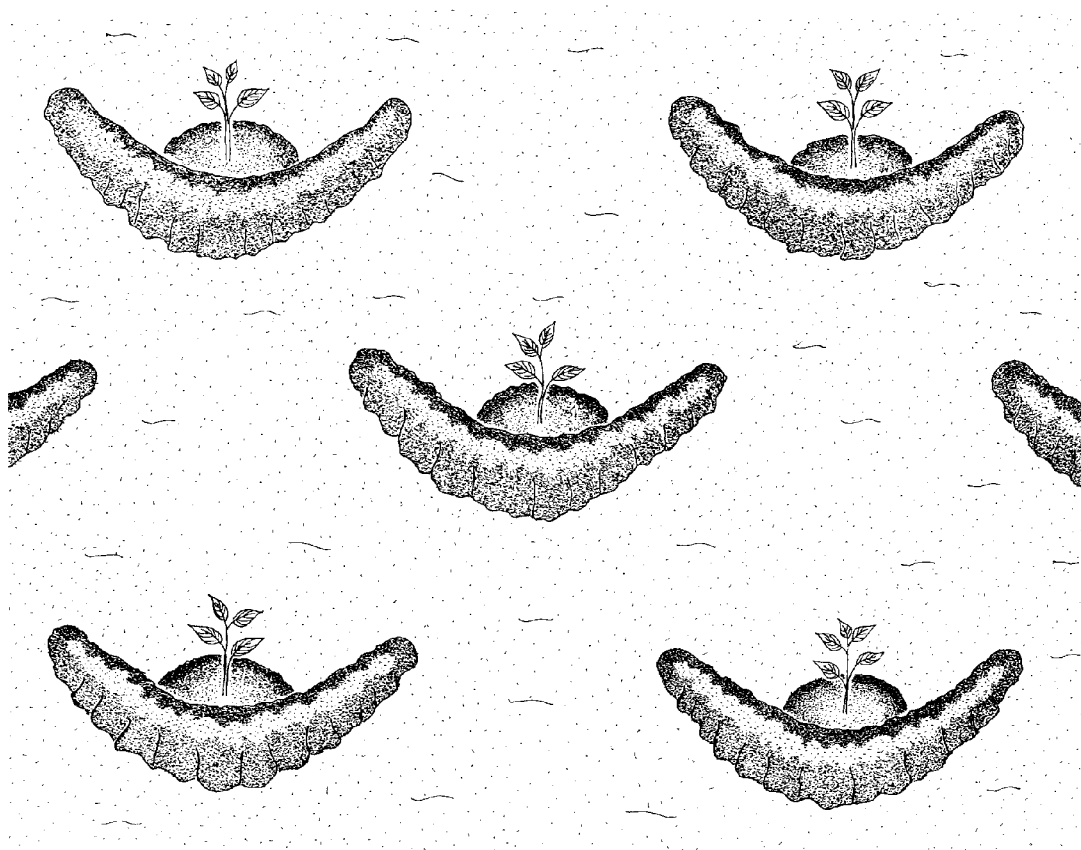
Semi-circular bunds are suitable on gentle slopes (normally below 2%) in areas with annual rainfall of 200-750 mm. The soils should not be too shallow or saline.

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

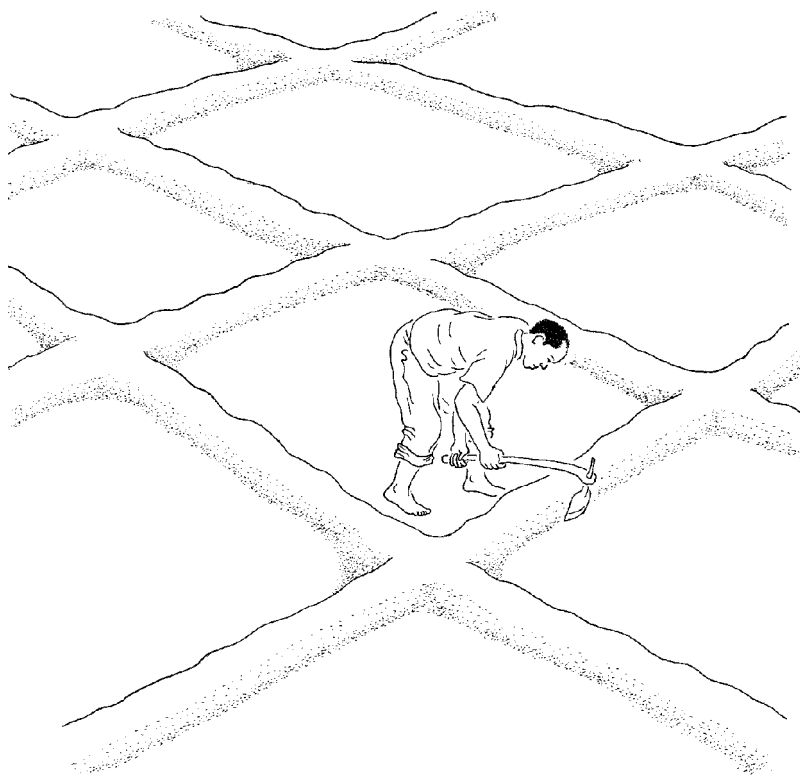
Earth basins are suitable in arid and semi-arid areas, with annual rainfall amounts of 150 mm and above. Soils should be deep, preferably at least 1.5 m to ensure enough water holding capacity. The slope can be from flat up to about 5%. If earth basins are constructed on steep slopes they should be made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

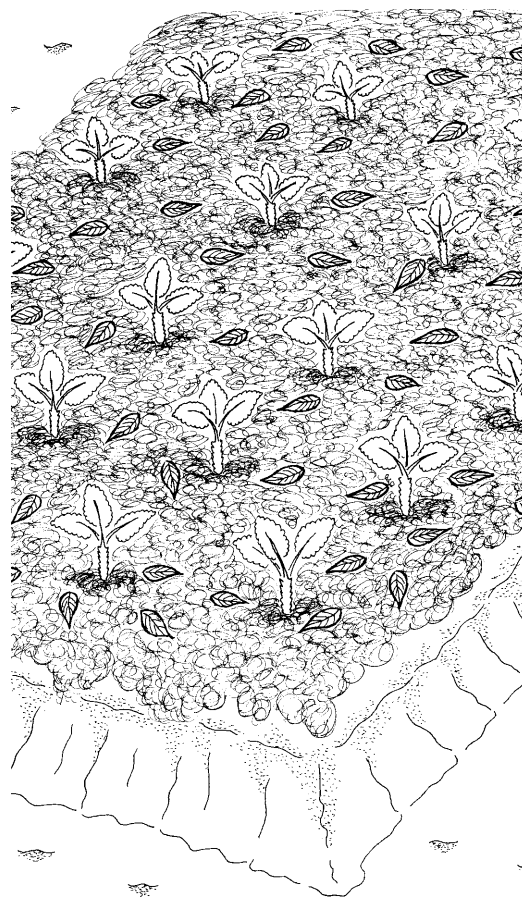
Areas with limited rainfall usually respond very well to mulching. Mulching is not applicable in wet conditions. The soils should have good drainage.

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

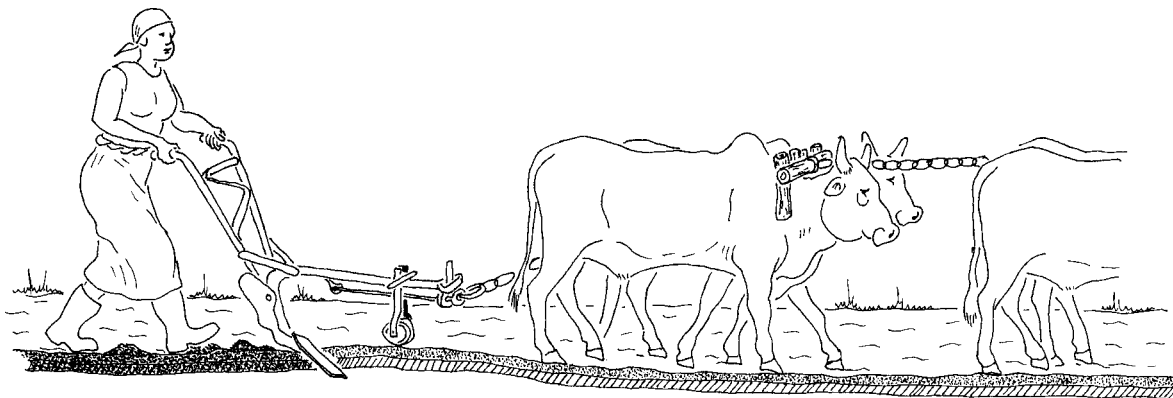
control crop diseases and pests and it also uses nutrient and mineral resource in the soil efficient since different crops will exploit different soil minerals at different times.

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