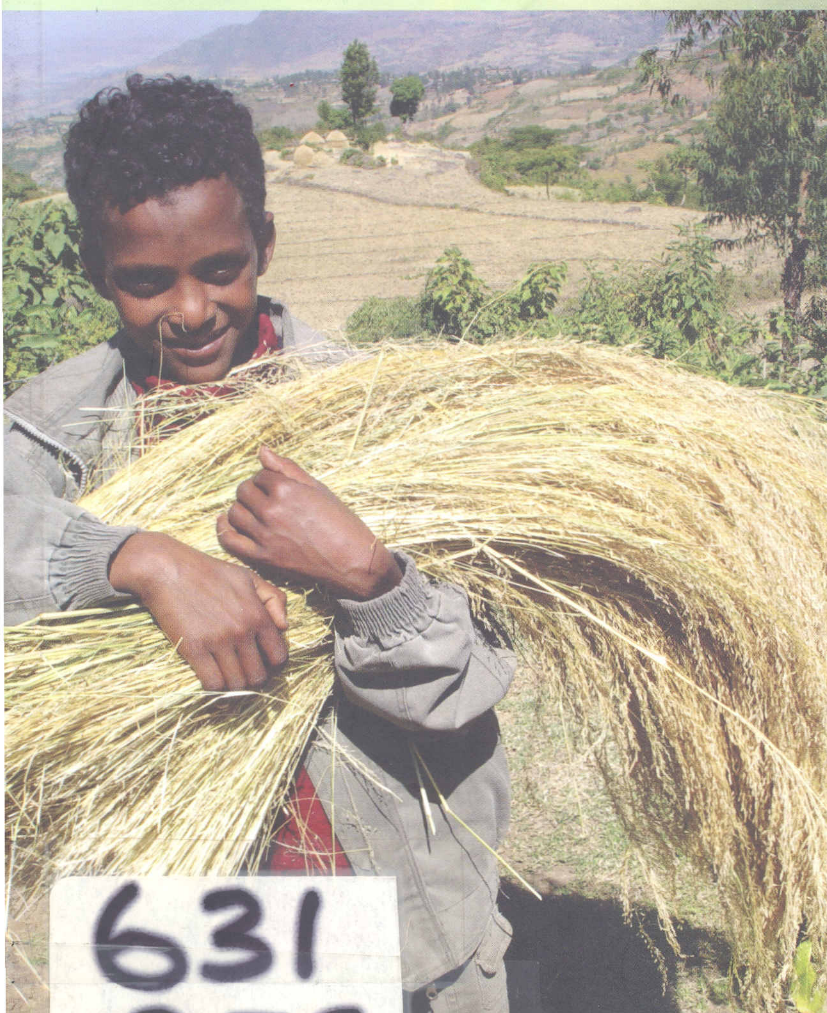
TECHNICAL HANDBOOK No. 36

Managing land

A practical guidebook for development agents in Ethiopia



Ministry of Agriculture and Rural Development, Ethiopia

RELMA

World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

Altitude		Mean annual rainfall: Dry (Less than 900 mm)	Moist (900–1400 mm)	Wet (More than 1400 mm)
Over 3700 m	Alpine Wurch	Dry Alpine Wurch	Moist Alpine Wurch	Wet Alpine Wurch
3200–3700 m	Wurch	Dry Wurch	Moist Wurch	Wet Wurch
2300–3200 m	Dega	Dry Dega	Moist Dega	Wet Dega
1500–2300 m	Weyna-Dega	Dry Weyna-Dega	Moist Weyna-Dega	Wet Weyna-Dega
500–1500 m	Kolla	Dry Kolla	Moist Kolla	Wet Kolla
Under 500 m	Bereha	Dry Bereha	Moist Bereha	

Agroclimatic zones in Ethiopia

Managing Land

Managing Land

A practical guidebook
for development agents in Ethiopia

RELMA

World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

Ministry of Agriculture and
Rural Development, Ethiopia

Regional Land Management Unit (RELMA in ICRAF)
World Agroforestry Centre—Eastern and Central Africa Regional Programme
and
Ministry of Agriculture and Rural Development, Ethiopia

Publisher
Regional Land Management Unit (RELMA)/ World Agroforestry Centre—Eastern and Central Africa Regional Programme, PO Box 30677 - 00100, Nairobi, Kenya, and
Ministry of Agriculture and Rural Development, PO Box 62347, Addis Ababa, Ethiopia

Series editor: Anna K Lindqvist, RELMA in ICRAF
Editing and layout (except covers): Paul Mundy, Bergisch Gladbach, Germany
Illustrators: Berhanu Mekonnen and Yetagesu Mergia
Cover design: Sandra Limley, S.Limley@gmx.de

Cover photographs

Left: Good land management gives a good tef harvest. Tikursu Watershed at Tarmaber Woreda, Amhara Region (by Azene Bekele-Tesemma)

Right top: Ploughing along the contour conserves the soil. Tikursu Watershed at Tarmaber Woreda, Amhara Region (by Alex Oduor)

Right bottom: Fruit is essential for good health, and can also provide income for the family. Kurar Watershed, Dejen Woreda at Gojam, Amhara Region (by Alex Oduor)

Cataloguing-in-publication data
Managing land: a practical guidebook for development agents in Ethiopia. 2005. Technical handbook No. 36. Nairobi: Regional Land Management Unit (RELMA in ICRAF)/ World Agroforestry Centre; Addis Ababa: Ministry of Agriculture and Rural Development. 282 p. + xiv p.

ISBN 9966-896-69-4

Printed in Dubai, by AG Printing & Publishing Ltd, Kenya. Tel: +254 2 4446560/4449775. Email: agpph@wananchi.com

Main contributing authors

Chapter 1 Introduction	Azene Bekele-Tesemma Håkan Sjöholm
Chapter 2 Working with communities	Azene Bekele-Tesemma Isaac Bekalo
Chapter 3 Managing land in each agroclimatic zone	Azene Bekele-Tesemma
Chapter 4 Managing soil fertility	Shelemew W/Mariam
Chapter 5 Conserving soil and water	Berhanu Fentaw Melesse Temesgen
Chapter 6 Managing water	Habtamu Gessesse Hune Nega
Chapter 7 Managing livestock and fodder	Gashaw Geda Getachew Felleke
Chapter 8 Managing trees and shrubs	Million Bekele Håkan Sjöholm
Chapter 9 Agroclimatic suitability of forages, trees, shrubs and crops	Getachew Felleke Gashaw Geda Håkan Sjöholm Million Bekele Shelemew W/Mariam

Supporting institutions

The production of this manual has been supported mainly by the following institutions:

Ministry of Agriculture and Rural Development
Ethiopia

Bureau of Agriculture and Rural Development
Amhara Regional State, Bahirdar, Ethiopia

Sida Amhara Rural Development Programme
Bahirdar, Ethiopia

Regional Land Management Unit (RELMA in ICRAF), Nairobi, Kenya

Swedish International Development Cooperation Agency, Sweden

Contents

Preface

I am proud to present this manual, *Managing Land: A Practical Guidebook for Development Agents in Ethiopia*. It has been produced in an unusual and innovative way, combining the skills and experiences of scientists, extension personnel and publications specialists. The Ministry of Agriculture and Rural Development authorized the specialists on each subject who contributed to the book, and RELMA in ICRAF added competence on some topics as well as its expertise in publications.

There is a tendency in academia to look at things in a strictly disciplinary way, to dig deep into each subject and discuss narrow topics. But small-scale land users have to be broad-minded. They have to think, plan and act holistically to make a decent living under often harsh conditions. For example, farming methods are based on knowledge of the natural sciences, but they also have to take economic and market aspects into consideration.

This manual is taking that into account. In discussing various subject areas, the manual includes complementary inputs from subject-matter specialists, and experiences and views from practitioners, and the chapters of the book are interlinked. Also, as Ethiopia is a tremendously varied landscape, for each of the techniques presented, there is also stated where they have potential to function well, and were not. Readers need only to know where they are located, at roughly what altitude, and with what mean annual rainfall. Such an entry into land management practices is unusual, elegant—and effective.

Natural conditions—climate and soil—are the framework for land management, but the cultural and social climate is also critical. That is why the chapter 'Working with communities' is important. Development agents should not talk to farmers but rather discuss with them, to reach a clearly understood balance between indigenous knowledge, practical experience and research findings. That is the approach of this manual, which ICRAF believes makes a real contribution to the growing amount of knowledge on sustainable land management—of which agroforestry is an important component.

It is my hope that this practical manual, which is in accord with Ethiopia's current land management policy, will be widely used.

Bashir Jama
Regional Coordinator
World Agroforestry Centre
Eastern and Central Africa Regional Programme

Foreword

It gives me a great pleasure to introduce the manual *Managing Land: A Practical Guidebook for Development Agents in Ethiopia*. This manual builds on the guidebooks *Soil conservation* (published in 1986) and *Community forestry* (1989). Both are currently out of print, and are in many aspects outdated. Based on agroclimatic zone conditions, as the two previous guidebooks were, this manual is a package of diverse, up-to-date and complementary subjects.

This manual aims to help development agents do a better job, together with farmers, in a multidisciplinary manner. Extra effort has been made to make the new guidebook simple to understand and use. It was developed with the participation of development agents themselves, and the subject matter specialists who were responsible for the various chapters have made strong efforts to ensure it contains up-to-date skills, methods and approaches. The development agents and many of the subject matter specialists are staff of the Ministry of Agriculture and Rural Development. Their contributions and effort are highly appreciated.

Ethiopia's varied altitude and rainfall results in significant differences in temperature, vegetation type and cover, land degradation and socioeconomic environments. So no land management blueprint would work everywhere. This manual covers land management and socioeconomic issues for each major agroclimatic zone.

Natural science is the basis for farming methods. But unless it is effectively connected to the principles of added value and the market, its impact on food security is limited. This book's recommendations for various development options are in line with this premise. In particular, the chapters on conserving and managing water show how to raise and sustain productivity of high-value crops.

All the chapters are interconnected. I strongly urge users to read each one, internalize the knowledge it contains, and establish the synergy between them.

As in many of our development efforts, the Regional Land Management Unit (RELMA) has been our assistant and instrumental in developing this manual. I would like to take this opportunity to thank RELMA and assure all that my ministry will champion its distribution and follow up its use. It is quite in tune with rural development policy of Ethiopia.

Belay Ejigu
State Minister
Ministry of Agriculture and Rural Development, Addis Ababa

Acknowledgements

The Ethiopian Ministry of Agriculture and Rural Development has been at the forefront in improving the land management in the country. Its interest, support and contributions to this book have been enormous. Without its support, the production of this book would not have been possible.

Production of the book has been possible because of the knowledge, financial and material contributions of many individuals and institutions. It is not possible to mention all of them.

The Swedish International Development Cooperation Agency (Sida), through its Regional Land Management Unit (RELMA, now part of the World Agroforestry Centre), has funded the bulk of the cost and has coordinated the production of this book. We appreciate its generous support. We also thank the RELMA director from 1999 to 2002, Åke Barklund, who took initiative and great personal interest in realizing the production of the book.

Thanks also to the ICRAF GIS Unit, especially George Aike, for preparing the maps.

We are thankful for the support of the Bureau of Agriculture and Rural Development of the Amhara Region, which has shared the cost of this manual.

The International Institute of Rural Reconstruction (IIRR) managed the writeshop process.

Sincere thanks to all the writeshop participants who contributed to this book. They are listed on page 270. Thanks also to the management and staff of the Red Cross Training Centre in Addis Ababa, where the writeshop was held.

The contributing authors

How this book was written

This manual is based on two earlier books published by the Ethiopian Ministry of Agriculture: *Soil conservation in Ethiopia* (1986) and *Community forestry in Ethiopia* (1989). These books have long been out of print. In 2001, the Ministry of Agriculture, through the Swedish Embassy in Addis Ababa, requested the Regional Land Management Unit (RELMA) to take on the production of revised, updated versions. It was agreed to combine the two books and to include other topics, such as agronomy, livestock, water management and extension approaches, to form a comprehensive manual on land management.

As was the case with the earlier books, it was decided that the new book should be designed for development agents who work directly with small-scale farmers. It should also emphasize the integration of various technologies.

The writeshop

The book was prepared through a 'writeshop' – a method pioneered by the International Institute of Rural Reconstruction (IIRR). Before the writeshop, authors were invited to prepare manuscripts on specific topics to be included in the manual. They were given guidelines on what their manuscripts should contain, the structure they should follow, and on the type of language to use. The authors submitted these manuscripts for comments by a small editorial team before the writeshop, and they revised the manuscripts to take these comments into account. They then brought these manuscripts with them to the writeshop.

The writeshop itself was held in Addis Ababa from 29 April to 9 May 2003. Participants included the manuscript authors, development agents (representing the intended users of the book), and specialists in the various subjects covered. A team of facilitators, editors, artists, desktop publishers and support staff assisted in the systematic review and revision of the manuscripts.

Each author presented his manuscript using overhead transparencies of the text. All participants then provided comments and suggestions on how the manuscript might be adapted or improved. The participants' task was to ensure that the manuscripts were not only technically correct, but also were relevant to the situation in the field and could be understood easily by development agents. Presentations were in English, but much of the discussion took place in Amharic. New manuscripts were also created during the writeshop, by individuals or groups, on subjects not yet covered. The participants also generated numerous case studies of practical experiences.

The team of four editors took turns to note the comments on each manuscript, and to assist the authors in the substantial revision and rewriting required. The editors also discussed possible illustrations with the authors, and commissioned artwork from the two artists. The revised text and draft illustrations were then passed on to computer specialists for desktop publishing.

Once a manuscript had been desktop published, it was handed back to the author, who presented it a second time. The participants made further comments and corrections, especially on the newly drawn illustrations. Again, the authors, editors and artists revised the text and illustrations to take these comments into account.

By the end of the writeshop, near-final versions of the text and illustrations were ready. It was then a relatively simple matter to make the final corrections and put it into final form.

Why a writeshop?

The writeshop process has been used to produce numerous easy-to-understand books, on subjects as diverse as ethnoveterinary medicine, sustainable agriculture, public awareness, dryland farming and gender issues. The process has several advantages over conventional methods of producing a book. It takes advantage of the presence of many different participants and staff, each of whom provides their own knowledge and expertise to each topic. Information can be generated, shared, checked for technical accuracy, translated into easily understood language, illustrated and re-checked, all at the same time. This considerably shortened the often-difficult process of writing, editing and publishing. In addition, the writeshop participants benefit from what is in effect an intensive training course: in the latest approaches for the extension workers among the participants, and in field realities for the scientists and policy makers.

We produced this book

Many people with different backgrounds and professions were involved in producing this book. They are listed in the *Appendix* (page 270).

1

Introduction

This chapter introduces two ideas that form the basis of this book.

- It describes the resources that farmers have available and the role of integrated land management in increasing production and conserving those resources.
- It introduces the major agroclimatic zones in Ethiopia and tells you how to identify the one you are in.

This chapter also explains how to use the rest of this book.

Integrated land management

In most parts of Ethiopia, the dependency on farming is extremely high, with 90% of the population being totally dependent on agriculture. Farm productivity is low – a result of a lack of agricultural inputs, outdated farming methods, deforestation, overgrazing, soil erosion, widespread land degradation, uncertain land tenure, and recurrent droughts, all in combination with high population pressure.

The land is managed by millions of smallholders. So to understand the situation fully, it is necessary to understand the individual farmer's situation.

The diagram on the next page shows the resources available to a typical farm family. The family has access to limited land – on average only about a hectare on the farm itself (on-farm resources) and the homestead. The farmland may be close to the homestead or at some distance away. To this can be added various off-farm resources such as forest and communal grazing areas.

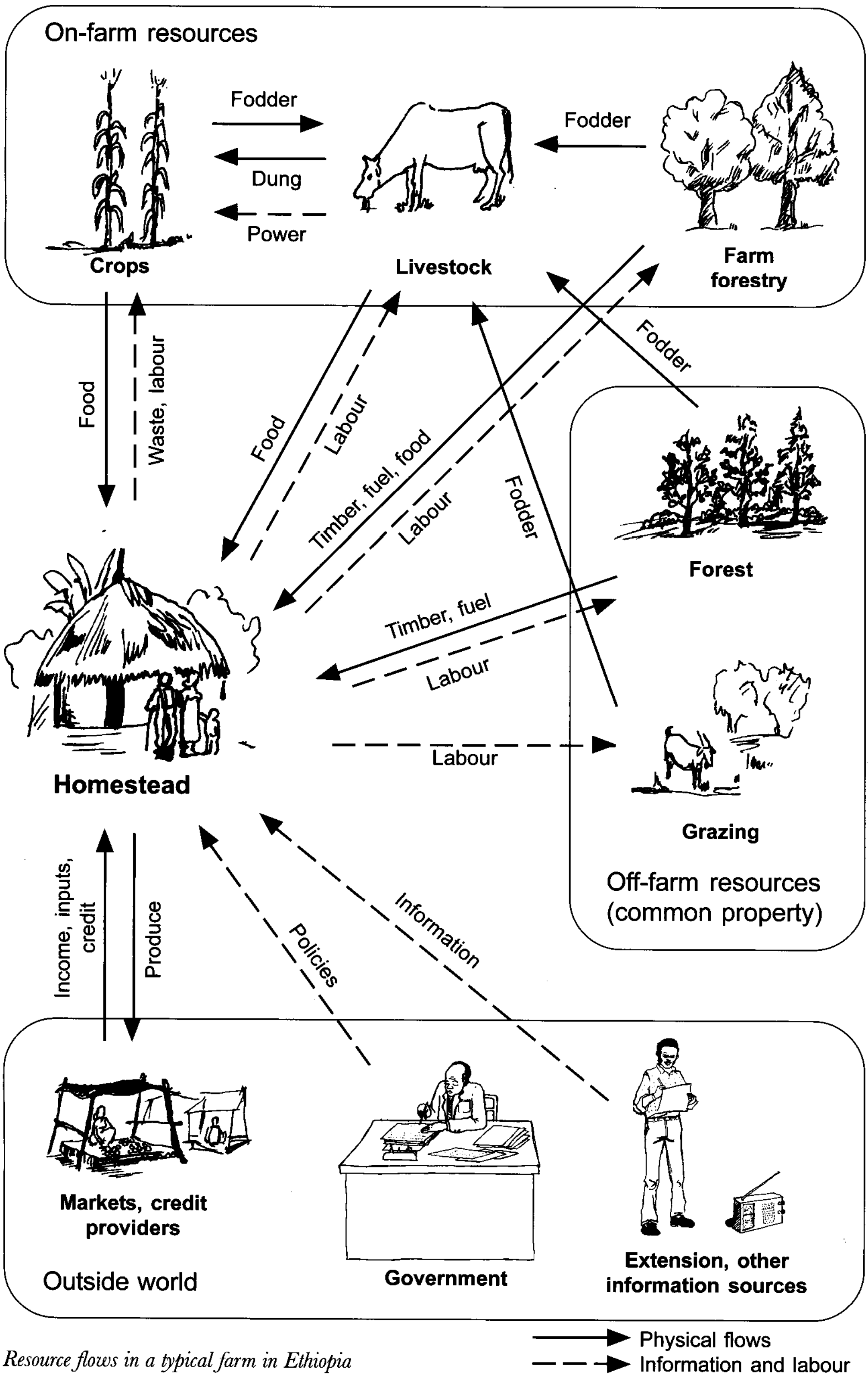
Yields are generally low. Farmers have little capital to invest in their farms, and can afford very few outside inputs such as fertilizer or improved seeds. They are forced to rely largely on their own labour, what they can grow themselves, and what they can gather from the immediate surroundings.

Livestock are an important component of the system. They provide draught power for working on the land, dung to improve soil fertility, food (meat, milk, eggs) and other products (hide, skin) for the family. The fodder needed to feed the animals comes from a number of sources. However, livestock are generally unproductive and of poor quality.

Forests are also important. They provide fuel (wood and charcoal), wood for construction, and various non-wood products. Farmers traditionally collected these products in the forest, but more and more are planting trees in and around their homestead, in the corners of fields, etc.

The land-use system shown in the diagram is very sensitive. To work, all the individual components must be in place and be fully operational, so that the flows (represented by the arrows) can occur. Subsistence farming can work well at low population levels with very little contact with the outside world. But this system is undermined by three major threats:

- Unreliable **rainfall** – drought and floods – reduces outputs and forces farmers to exploit already overused resources further.
- High **population** pressure results in overgrazing and the cultivation of slopes, causing soil erosion, destroying tree cover, and degrading the land.
- Rising populations put even more pressure on the **environment**. New areas are opened up for farming every year: forests are disappearing, and steep slopes and areas traditionally used for grazing are being cultivated.



Resource flows in a typical farm in Ethiopia

Ethiopian farmers face many problems in trying to make a living in these conditions. They usually have detailed knowledge of their local situation (the soils, climate, crops and animals), but most have limited knowledge or skills in improved technologies. They lack basic educational and health facilities. They are short of cash and credit to invest in their farms and to buy inputs. This makes it very difficult for them to pull themselves out of poverty.

To combat these trends and to increase outputs, farmers must use appropriate land management measures. Without such interventions, the whole system may simply collapse. Appropriate interventions include:

- Measures that directly increase production, such as using fertilizers, improved seeds, and new farming methods.
- Measures that protect the resources that farmers rely on (soil, water, trees), and that prepare for and mitigate drought. These include controlling erosion, protecting forests, planting trees and building water storage tanks.

More intensive contacts with the outside world are necessary for this to happen. These contacts include access to markets for produce, information and skills to apply new technology, appropriate levels of credit to invest in farms, and advice about government policies. A major role of development agents is to help farmers access these resources (at the bottom of the diagram on the previous page).

A second major role of development agents is to help farmers help themselves. By organizing as groups, rural people can achieve goals that would be impossible for them to reach individually. Chapter 2 of this book, *Working with communities*, has some ideas on how to do this.

Appropriate technologies can be introduced, soil fertility can be improved, trees can be planted. But technical solutions are often overshadowed by problems outside the agricultural sector: the lack of infrastructure, poor access to markets, institutional weaknesses, lack of credit, and so on.

Agroclimatic zones of Ethiopia

Ethiopia has remarkably diverse landscapes. Altitudes range from 120 m below sea level (in the Danakil desert) up to 4,620 m above sea level (in the Simien mountains). The mean annual rainfall ranges from less than 100 mm to 2,400 mm per year. Daytime temperatures range from 2°C and 43°C. The soils vary in colour, texture, fertility and extent of degradation. The natural vegetation includes mountain steppes, savannah, woodland, forest and lowland scrub.

The two most important climatic factors from a farmer's or development agent's point of view are **temperature** (which is determined by the **altitude**) and **rainfall**. These have a major influence on what crops farmers grow, how they keep their livestock, and how they manage their land.

Altitude

There are six altitude layers in Ethiopia. From highest to lowest, they are:

Alpine Wurch	higher than 3700 m above sea level
Wurch	3200–3700 m
Dega	2300–3200 m
Weyna-Dega	1500–2300 m
Kolla	500–1500 m
Bereha	below 500 m

The map on page 6 shows these altitude layers.

Rainfall

There are three rainfall categories:

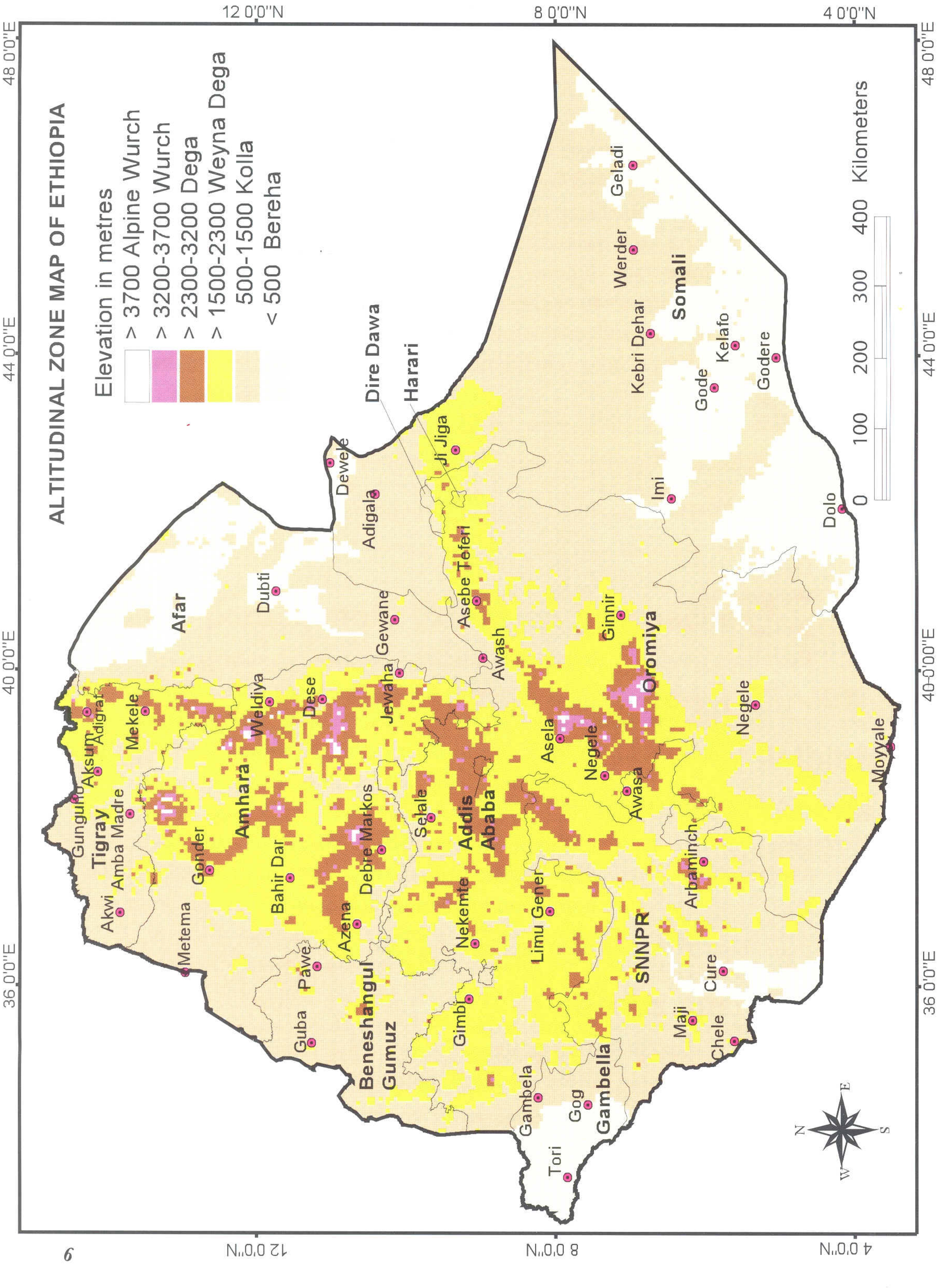
Dry	less than 900 mm of rain a year
Moist	900–1400 mm
Wet	more than 1400 mm

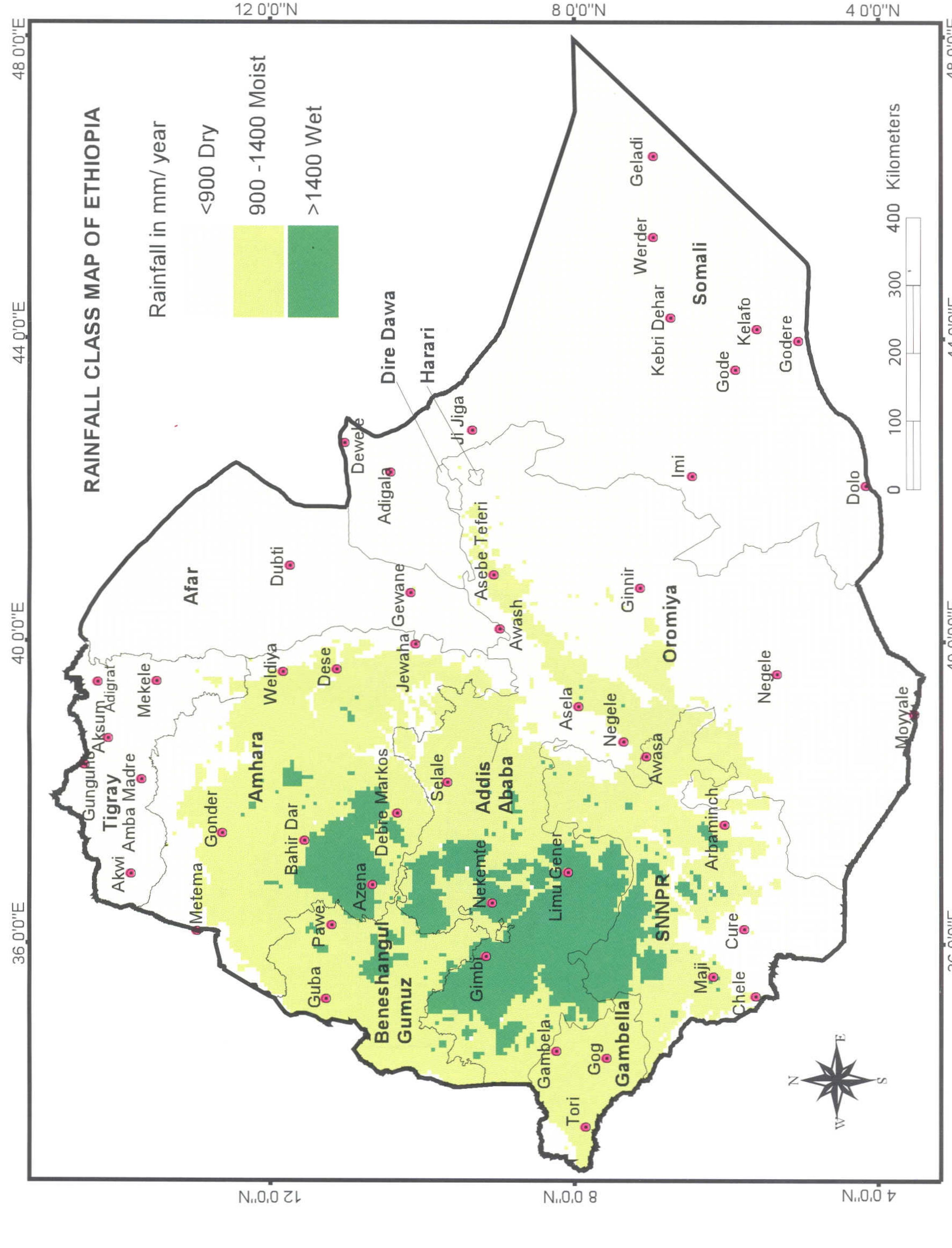
The map on page 7 shows these rainfall categories.

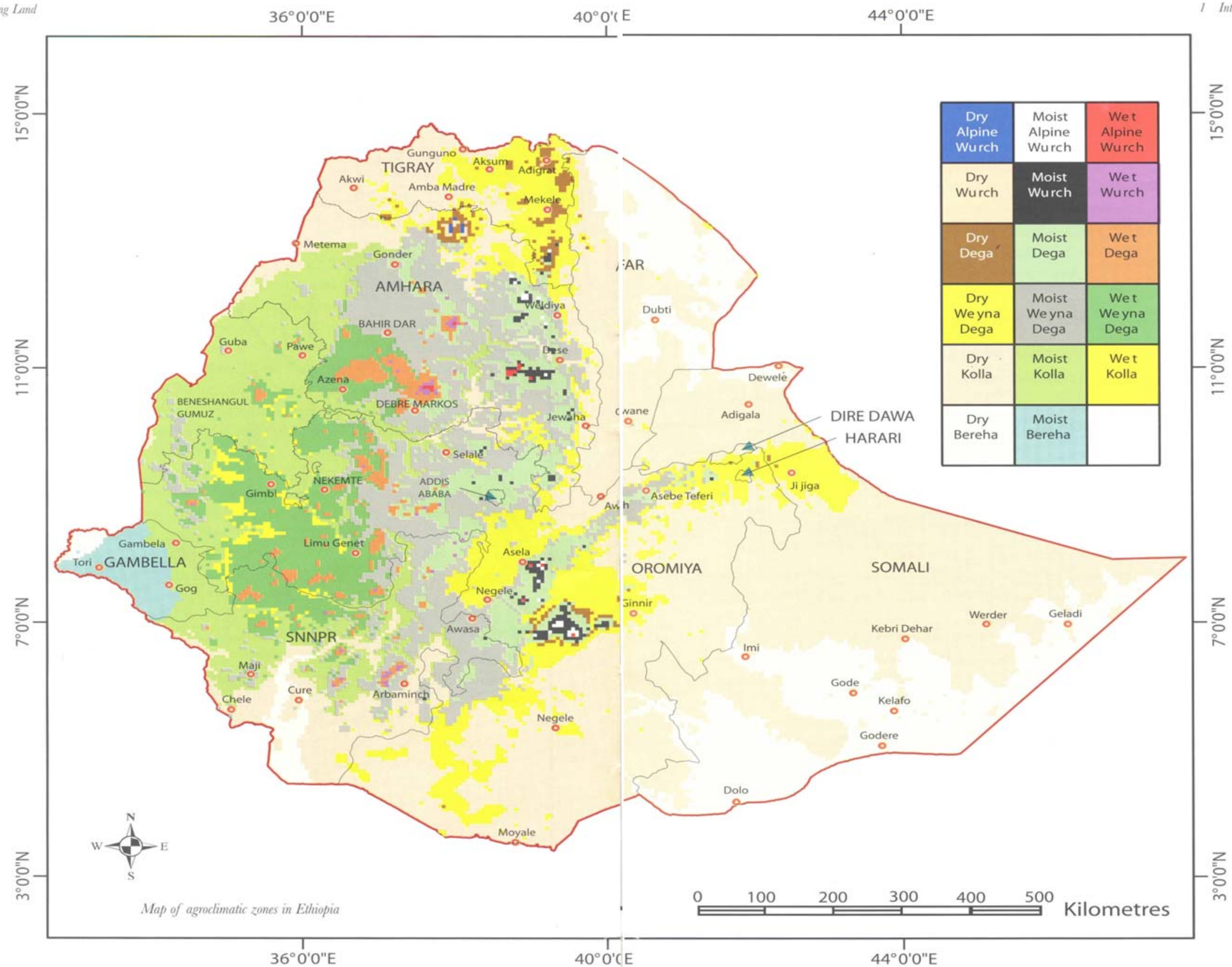
Agroclimatic zones

The rainfall categories cut across the altitude levels, giving three agroclimatic zones at each altitude. For example, within the Dega altitude layer (2300–3200 m), there are three agroclimatic zones:

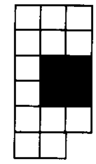
- Dry Dega (less than 900 mm of rain a year)
- Moist Dega (900–1400 mm)
- Wet Dega (above 1400 mm).


ALTITUDINAL ZONE MAP OF ETHIOPIA
Elevation in metres
> 3700 Alpine Wurch
> 3200-3700 Wurch
> 2300-3200 Dega
> 1500-2300 Weyna Dega
500-1500 Kolla
< 500 Bereha
0 100 200 300 400 Kilometers
12 0'0"N
8 0'0"N
4 0'0"N
48 0'0"E
44 0'0"E
40 0'0"E
36 0'0"E
Tigray
Afar
Amhara
Dire Dawa
Harari
Somali
Oromiya
Addis Ababa
SNNPR
Beneshangul Gumuz
Gambella
Gunguno
Aksum
Adigrat
Mekele
Amba Madre
Akwi
Metema
Gonder
Weldiya
Dese
Jewaha
Bahir Dar
Debre Markos
Azena
Pawe
Guba
Dubti
Gewane
Adigala
Dewele
Ji Jiga
Asebe Teferi
Awash
Selale
Nekemte
Limu Gener
Gimbi
Gambela
Gog
Tori
Asela
Negele
Awasa
Ginnir
Arbaminch
Cure
Maji
Chele
Moyyale
Geladi
Werder
Kebri Dehar
Gode
Kelafo
Godere
Imi
Dolo
N
E
S
W


RAINFALL CLASS MAP OF ETHIOPIA
Rainfall in mm/ year
<900 Dry
900 -1400 Moist
>1400 Wet
0 100 200 300 400 Kilometers
12 0'0"N
8 0'0"N
4 0'0"N
48 0'0"E
44 0'0"E
40 0'0"E
36 0'0"E
Tigray
Afar
Amhara
Dire Dawa
Harari
Somali
Oromiya
Addis Ababa
Beneshangul Gumuz
SNNPR
Gambella
Akwi
Amba Madre
Gunguho
Aksum
Adigrat
Mekele
Metema
Gonder
Weldiya
Dese
Dubti
Dewele
Adigala
Gewane
Jewaha
Ji Jiga
Asebe Teferi
Awash
Bahir Dar
Debre Markos
Selale
Azena
Pawe
Guba
Nekemte
Gimbi
Limu Gener
Gambela
Gog
Tori
Asela
Negele
Awasa
Arbaminch
Cure
Maji
Chele
Ginnir
Imi
Geladi
Werder
Kebri Dehar
Kelafo
Gode
Godere
Dolo
Moyyale
N
E
S
W



Map of agroclimatic zones in Ethiopia



By combining the six altitude layers with three rainfall categories, one could get 18 **agroclimatic zones**. However, there is no land below 500 m altitude that receives more than 1400 mm of rain – so there is no Wet Bereha zone. In addition, the Dry and Wet Alpine Wurch and Dry Wurch zones cover less than 500 km^2 and are unimportant for agriculture. The remaining 14 zones are covered in this book.

Throughout this book, small diagrams show where particular land management techniques can be used. An example of these diagrams is shown above. The four shaded squares in this example represent the Moist and Wet Dega, and the Moist and Wet Weyna-Dega zones.

Of course, a land management technique might be useful in other zones, but you should be especially careful if you recommend it there. Try to test it on a small scale before you do so.

The map on pages 8 and 9 shows the location of the various agroclimatic zones. This map is a guide only: it cannot show all the local variations in altitude and climate, as these can vary greatly over a short distance. So you should not rely on it too much to determine whether a particular location lies in one zone or another.

How to identify your agroclimatic zone

You can identify your agroclimatic zone in different ways:

- **Altitude** Use an altimeter to measure the altitude, or check a contour map of the area.
- **Rainfall** Visit the nearest agriculture office to ask for rainfall data.

You can also ask someone who has worked there before you.

Once you know the altitude and mean annual rainfall, you know what zone you are in. For example, if the local rainfall area is 1000 mm and the altitude is 2000 m, then you must be in the Moist Weyna-Dega zone.

But accurate information on rainfall and altitude for a particular place may be hard to get. Luckily, you can use other factors, such as common agricultural crops, soil conditions and vegetation types to tell you which zone you are dealing with. This is because vegetation, crop and soil conditions depend largely on the climate.

The table on the next page shows the main crops, soils, natural vegetation and traditional conservation problems and methods found in each of the zones.

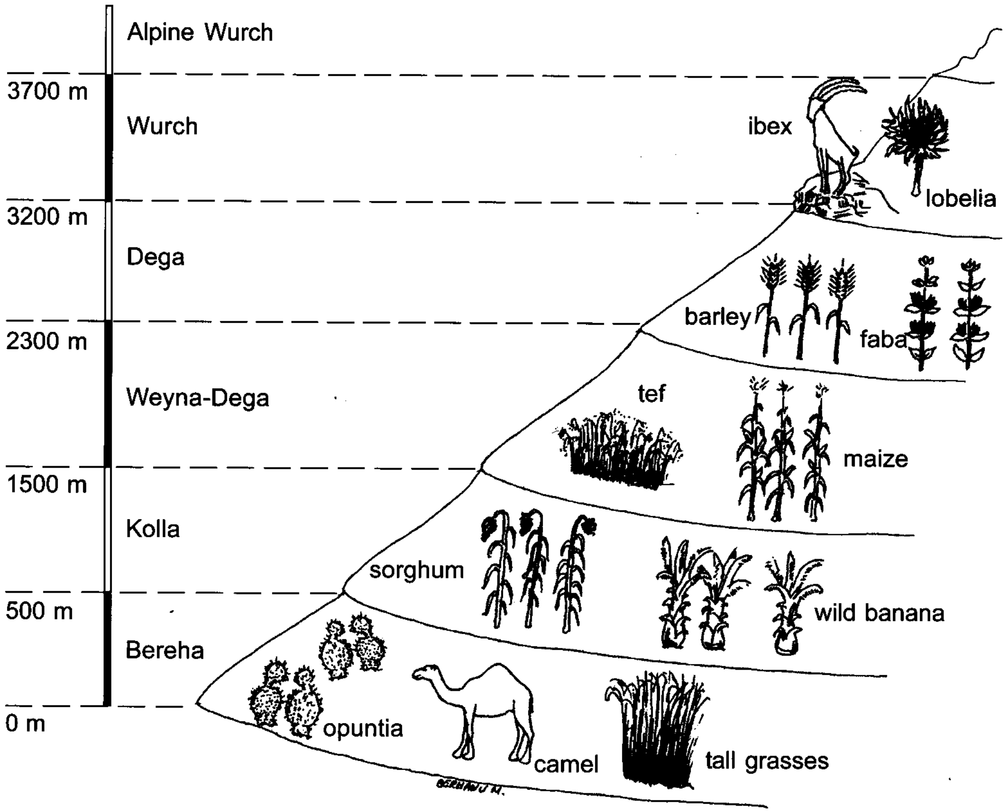
If you know only the altitude (for example, if a map shows you are below 500 m, so are in the Bereha zone), you can determine whether your site is dry, moist or wet. Look at the type of natural vegetation, the soils, the cropping practices (or the

Facing page: Features of agroclimatic zones

How to use this table: First find your altitude (Wurch, Dega, Weyna-Dega, etc.). Then compare the crops, traditional conservation practices, soils and natural vegetation nearby with those listed in the table to find whether you are in the Wet, Moist or Dry zone.
(Adapted from Bekele-Tesemma, 1997)

Altitude	Dry Less than 900 mm	Moist Mean annual rainfall 900–1400 mm	Wet More than 1400 mm
Alpine Over 3700 m	**Dry Alpine Wurch**	**Moist Alpine Wurch** *Crops* None but wildlife *Cons* None *Soil* Black, shallow *Veg* *Hypericum quartini-anum, Hypericum roeperianum*	**Wet Alpine Wurch**
Wurch 3200–3700 m	**Dry Wurch**	**Moist Wurch** *Crops* Potatoes and barley, single cropping per year *Cons* Drainage rare *Soil* Black, degraded *Veg* *Erica, Hypericum, Croton macrostachyus* (dwarfed)	**Wet Wurch** *Crops* Potatoes and barley, 2 crops per year *Cons* Widespread drainage ditches *Soil* Black, highly degraded. *Veg* *Erica, Hypericum* spp.
Dega 2300–3200 m	**Dry Dega** *Crops* Barley, wheat, pulses *Cons* Traditional moisture conservation measures *Soil* Grey–brownish grey *Veg* *Olea europaea, Maytenus undata, M. senegalensis*	**Moist Dega** *Crops* Barley, wheat and pulses *Cons* Few traditional terraces *Soil* Brown clay *Veg* *Juniperus procera, Hagenia abyssinica, Podocarpus falcatus*	**Wet Dega** *Crops* Barley, wheat, nug, pulses, 2 crops/year *Cons* Widespread drainage ditches *Soil* Dark brown, clay *Veg* *Juniperus procera, Hagenia, Podocarpus falcatus, Arundinaria alpina*
Weyna-Dega 1500–2300 m	**Dry Weyna-Dega** *Crops* Wheat, tef, rarely maize *Cons* Terracing widespread *Soil* Light brown, yellow *Veg* *Acacia drepanolobium, A. seyal*	**Moist Weyna-Dega** *Crops* Maize, sorghum, tef, enset (rare), wheat, *nug*, finger millet, barley *Cons* Traditional terracing *Soil* Reddish brown *Veg* *Acacia, Cordia africana, Ficus* spp.	**Wet Weyna-Dega** *Crops* Tef, maize, enset (in west), *nug*, barley *Cons* Widespread drainage *Soil* Red clay, deeply weathered, gullies *Veg* *Acacia, Cordia, Polyscias fulva*
Kolla 500–1500 m	**Dry Kolla** *Crops* Sorghum, rarely tef *Cons* Water retention terraces *Soil* Yellow, sandy *Veg* *Acacia tortilis, A. nilotica, A. bussei*	**Moist Kolla** *Crops* Sorghum, tef, *nug*, finger millet *Cons* Widespread terracing *Soil* Yellow, silty *Veg* *Acacia, Erythrina, Cordia, Ficus* spp.	**Wet Kolla** *Crops* Mango, taro, sugarcane, maize, coffee, citrus *Cons* Ditches frequent *Soil* Red clay, highly oxidized *Veg* *Milicia excelsa, Cyathea manniana*
Bereha Under 500 m	**Dry Bereha** *Crops* Only with irrigation *Cons* Wind erosion common *Soil* Aridosols, regosols, silty, sandy and gravelly *Veg* *Acacia senegal, Acacia bussei, Tamarix aphylla, Commiphora holtziana, Opuntia vulgaris*	**Moist Bereha** *Crops* Seasonal rainfed agriculture possible *Cons* Burning grasses common, no wind erosion *Soil* Silty and clayey, mainly black *Veg* *Ziziphus pubescens, Antiaris toxicaria, Erythroxylum fischeri*	

Crops: Main crops
Cons: Traditional soil conservation
Soil: Soil on slopes
Veg: Natural vegetation



Typical crops and animals at different altitudes

lack of them), and traditional soil conservation measures. Then check them against the table.

Check the characteristics that are different from one zone to another. For instance, in the Dry Bereha zone, cropping is impossible without irrigation, and wind erosion is common. In the Moist Bereha zone, on the other hand, crop farming is possible, tall grasses cover terraces and retention ditches, and there is little wind erosion.

You can use a similar approach to distinguish the Dry, Moist and Wet Kolla zones. In the Dry Kolla, you will only occasionally find rainfed sorghum. Tef is grown widely. Soils are yellow and sandy. Farmers grow onions, pepper and sugarcane using traditional irrigation. Conservation measures aim to retain moisture. In the Moist Kolla, sorghum is a favourite crop. Niger seed (*nug* in Amharic) and millet are also grown. Soils are yellowish and silty. In Wet Kolla, soils are generally red. Perennial crops such as mango, taro, sugarcane, banana, coffee and citrus are popular. You will also find moisture-loving trees such as *Cyathea manniana* (*gonji* in Kefigna) and wild banana.

The Alpine Wurch is a special zone. At this altitude there is no agriculture because of the freezing conditions. The natural vegetation is mainly grass with scattered giant lobelia and *Hypericum roeperianum*.

For specific descriptions of problems, opportunities and practices suited to the different agroclimatic zones, see Chapter 3.

Using this book

Effective land management and the wise use of natural resources have paramount importance to Ethiopia farmers. Development agents can play a major role in helping them. They are the farmers' closest assistants. This book aims to help development agents help farmers to manage their land effectively.

Parts of this book

This book's nine chapters focus on some of the critical aspects of land management in Ethiopia.

- **Chapter 1** (this chapter) is the **introduction** to the rest of the book. It describes integrated land management, gives a guide to the 17 agroclimatic zones in Ethiopia, and explains how to use this book.
- **Chapter 2** focuses on how to **work with communities**. It covers participatory extension methods, farm planning, working with groups, gender issues, and how to deal with the twin scourges of HIV/AIDS and drought.
- **Chapter 3** describes the **land management** options in each of the major agroclimatic zones in Ethiopia. For each zone, it outlines the problems, potentials and opportunities, and the land management measures and options appropriate to that zone.
- Chapters 4 to 6 focus on soil and water management. **Chapter 4** describes techniques to maintain and improve **soil fertility**.
- **Chapter 5** covers methods to prevent **soil erosion** and **conserve water** in the field.
- **Chapter 6** gives guidelines on **water management**: how to collect and store water, and how to use it to irrigate crops.
- **Chapter 7** focuses on **livestock**-related aspects of land management: the growing of fodder, and grazing and feeding strategies.
- **Chapter 8** describes **tree management**, from establishing a nursery to planting and managing trees in woodlots, on farms and to rehabilitate degraded land.
- **Chapter 9** lists major **species** – forages, trees, field crops and horticultural crops for each of the major zones. It also provides references for further reading.

At the end of the book is a list of **references** for further reading on topics related to land management in Ethiopia.

The **Index** lists the technologies and plant species mentioned in the book.

How to use this book

This book can be used in many ways. You do not have to read it in any particular order. Here, though, is a suggestion for how to make the best use of it.

First, if you have not already done so, read **Chapter 1**. This will help you understand the ideas behind integrated land management. Use the guide to identify which agroclimatic zone you are working in. The small diagrams throughout the book show you which zone each technique is best suited for.

You should then read **Chapter 2** on *Working with communities*. The section on *Participatory extension approaches* describes how to help the farmers in a community assess their problems and plan ways to solve them.

Now check under your agroclimatic zone in **Chapter 3**. This will tell you the major problems in your zone and some of the potentials and opportunities it may offer. You will also find lots of technologies that you can recommend for the farmers.

Chapters 4 to 8 give details about these technologies and how to implement them. You can find the technique you want by checking the *Table of Contents* or the *Index* at the end of the book. You can also flip through the book to see if a technique is suited to your area by checking the small diagrams at the top right of each page.

The most appropriate technologies in each place depend not only on the local temperature and rainfall (as reflected in the agroclimatic zone). The soils and slopes may also be important. Make sure that you check these carefully before recommending a particular technology to farmers.

The local socioeconomic conditions, transport, communications, markets and culture are equally important. You should also take these into account when advising farmers. If you advise them to grow a crop they cannot sell, they are unlikely to listen to you again.

Refer to the lists of species in **Chapter 9** whenever you need to check whether a particular species is appropriate in a particular agroclimatic zone.

Throughout, the focus is on you, the development agent, and the advice that you can give to smallholders. This book is written in simple language, avoiding technical terms where possible. It uses lots of pictures. Show these to farmers if you think it will help them understand what is said.

This book does not mean to cover large, commercial, capital-intensive farms, or the management of state forests. While it tries to provide as much detail as possible, it cannot give technical details on specialist topics such as irrigation or the construction of water tanks. You should consult an expert in these areas for advice.

2

Working with communities

Solving technical agricultural problems (Chapters 4 to 8) is just part of a development agent's job. Perhaps a bigger and more challenging part involves working with people rather than plants and animals. Development agents need to know how best to work with the people they serve – the farmers.

Traditionally, extension in Ethiopia has been top-down, with the extension service telling farmers what to do. This approach is not very effective. As soon as the development agents' backs are turned, the farmers return to their previous practices.

Participatory approaches take more time and effort, but they are more effective in the long run. They require a different set of skills on the part of the development agents: skills in listening, facilitating and organizing, rather than deciding and instructing.

This chapter covers participatory approaches to extension, farm planning, and working with groups. It also describes how to take gender and HIV/AIDS into account in extension work, and what to do at various stages during the drought cycle.

Participatory extension approaches

There is no one ideal technology in land management that is applicable everywhere. Farmers must choose and adapt technologies according to their particular situation: the best one to use will depend on the slope, soil type, agricultural production system, landholding pattern, and many other factors. Often farmers can choose from a number of alternatives.

The same is true for extension approaches. There is no one best approach. It must be adapted to the local situation, in terms of agroecology and socioeconomics. Nevertheless, certain extension tools are useful, and we can outline some basic principles that development agents should try to follow.

A number of extension approaches have been used in Ethiopia over the years. These have often been top-down, with the extension agent instructing farmers, and with little room to accommodate the farmers' opinions. All too often, this directive approach has failed. The advice has been inappropriate; farmers feel forced to do something before they are convinced it is a good idea, and they soon stop doing it.

What are participatory extension approaches?

Participatory extension approaches avoid the problems of top-down extension. They aim to enable local people to take part in making the decisions that affect them, rather than having their lives shaped for them. People discuss issues, identify and prioritize problems, seek solutions, and plan what to do. They then carry out the plans they have made, and monitor and evaluate what they have done.

Participation can ensure that activities are based on local knowledge, values and priorities. Activities should be small-scale and adapted to local skills and technology. Local organizations and structures can help manage activities and mobilize resources. This community involvement enhances accountability, increases the sense of ownership, and improves the care and maintenance of bunds, ditches and other structures.

Participatory approaches are particularly useful for land management. If people themselves decide to build a set of terraces, they are likely to maintain them and repair them when they are damaged. If they decide to create a livestock-exclusion area, they are likely to keep their own and their neighbours' animals out, to conserve the improvements they have made inside the area.

Development agents play a vital role in participatory approaches to land management. Their role is very different from that of the traditional extension agent. They play the role of a facilitator rather than instructor. They help organize groups, discuss issues, identify and prioritize problems, develop and implement plans, and test potential solutions. They can also provide suggestions, identify sources of information and credit, and link farmers to outside agencies that can help them. Throughout, they use simple language that farmers can understand easily.

This approach is very different from the one that many development agents are used to. It calls on a different set of skills. Perhaps more important, it requires a different set of attitudes on the part of the development agents and the organizations they work for. They must be ready to learn from the local people, accept their point of view, and promote farmers rather than themselves as leaders.

Advantages of participatory approaches

Participatory extension approaches have numerous advantages:

- They take advantage of what farmers already know (their **indigenous knowledge**).
- They increase the **appropriateness** of the activity, since farmers can choose options they think are best suited to their particular situations.
- They build **ownership** among farmers for the activity (soil conservation work, rangeland management, etc.).
- They improve the **sustainability** of the activity: they increase the likelihood that the farmers will continue it of their own accord.
- They help **coordinate activities** and **avoid conflicts** among farmers (for example, between neighbouring landholders) because decisions are made as a group.
- They increase **empowerment** by enabling farmers to make their own decisions and by building community capacity.
- They facilitate **cost-sharing** between the local community and the government or development agency.
- They help organize effective, committed, sustainable **groups** which can work together.

Limitations and constraints

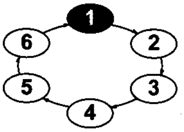
Despite these advantages, participatory approaches tend to suffer from various disadvantages:

- They may be **time-consuming**.
- They may lead farmers to have **high expectations**, and to be disappointed when these expectations are unfulfilled.
- There is a tendency for the extension agent to **manipulate** the farmers, instead of facilitating them to make their own decisions.
- Some people may become '**free-riders**' – they take the benefits of the activities without doing any of the work.
- A few people can **block** changes that others want, or can influence the group in undesirable ways. This is especially a problem if those people are formal leaders who have a hidden agenda.

Steps in participatory approaches

Participatory approaches generally consist of a number of steps (see the diagram below).

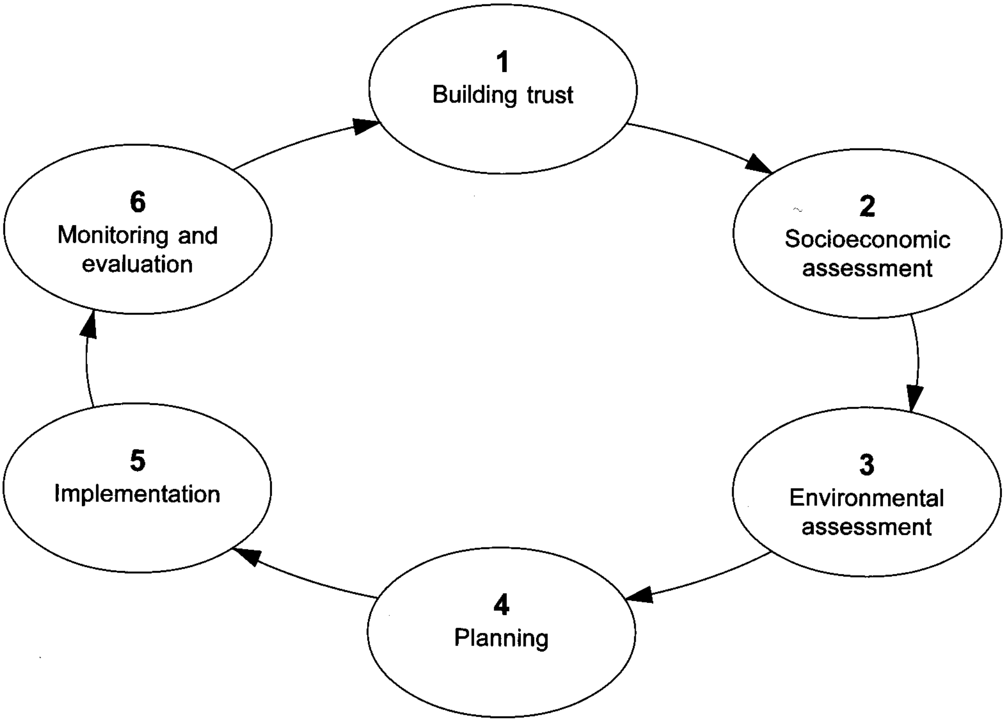
1 Building trust



Development agents must know the people they serve, and the local community must in turn know and accept them. The development agent should aim to be seen as a trusted friend by the community. Many development agents live in the villages they serve, so there is ample opportunity for this to happen. But it does not happen automatically.

The development agent must:

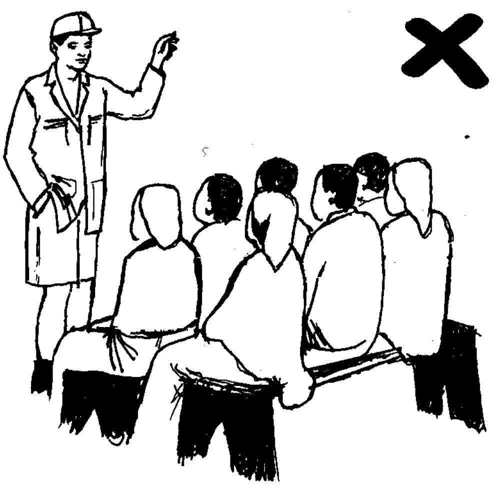
- Get to know the local people, their lives and the local area.
- Find out when and where people prefer to meet, and who (and how many people) should be invited to meetings.
- Identify innovative and volunteer farmers who might try out and promote improved land management methods.
- Identify formal and informal leaders and other key players in the community.



Steps in participatory planning and implementation (source: Bekele-Tesemma, 1997)

Local people are often suspicious of outsiders – especially of young government officials like many development agents. But trust is vital if the development agent is to be accepted. Here are some ideas on how to build trust:

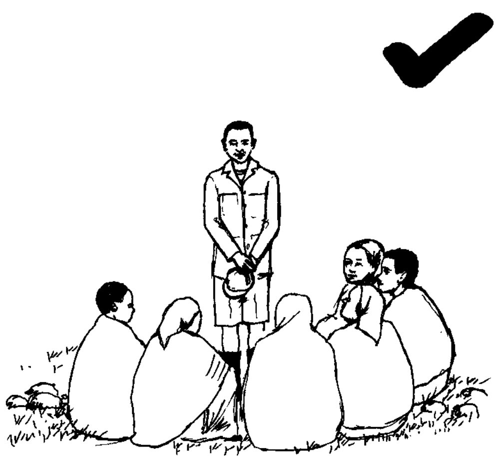
- Stay in the community.
- Learn local values and customs, and follow them where appropriate. For example, attend celebrations and funerals, and accept invitations. Use appropriate body language – for example, stand or sit when appropriate, take your hat off when addressing groups, and so on.
- Treat local people with courtesy and deference. Respect their knowledge and opinions.
- Learn the local language.
- Cultivate good relations with local leaders (elders, religious leaders, etc.). Acquaint them with your activities and ask for their help and advice. Involve them in activities, and work with them, and through them, where possible.



A bad approach. This development agent is lecturing to farmers sitting in rows. It is hard for the farmers exchange ideas with each other.

Local values vary from place to place in Ethiopia. What may be usual behaviour in one place may not be acceptable elsewhere. Developing trust requires interest, commitment and effort on the part of the development agent.

Building trust is not a one-off activity. It takes time, and continues throughout the development agent's work with the community. Trust is precious: once lost, it is very difficult to regain.

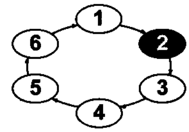


A better approach. This agent is treating the farmers with respect. The farmers are sitting in a circle, so they can discuss with each other as well as ask questions.

Outcomes

As a result of building trust, the development agent will know and understand the local people. He or she will be familiar with local norms and values, and will know who the local leaders are – and who can be relied on to take leadership in improving land management. Local people will accept the development agent, and the agent and local people will have confidence in each other.

2 Socioeconomic assessment



Development efforts often fail because they do not fit with local socioeconomic realities. Development agents should try to understand:

- **Institutions** What the local institutions are, how local power relations work, how the community is governed, and how it deals with conflicts and issues.
- **Agricultural systems** What the socioeconomic issues are relating to crops, livestock and feed, forestry (including energy needs), soil and water management, pasture management, and so on; the seasonal calendar of crop and livestock production and labour requirements, what they see the problems and potentials are, and how they have tried to deal with these issues in the past.
- **Economics** The economic importance of various farm activities, the potential for developing these, and other sources of income (including credit).
- **Gender and labour issues** The role of women, men and children in agricultural production, seasonal variations in labour needs, the timetable of people's daily activities, and so on.
- **Indigenous knowledge** Local people's knowledge, skills and technologies in land management and related areas.
- **Society and culture** Families, groups, relationships, education, customs and values.
- **History** How the community adapts over time, including experiences with migration and responses to drought.

Participatory assessment and analysis

As part of this process, the development agent can help the local people analyse their situation and constraints, and their needs, aspirations and goals. The following methods can be used to gather and analyse information:

- Informal observations and discussions with key informants.
- Discussions with groups of people who share particular interests.
- Discussions with people while helping them do work such as weeding and threshing.
- Semi-structured group interviews.
- Participatory rural appraisal techniques. Maps, problem trees, timelines, calendars, timetables and Venn diagrams are particularly useful.
- Consulting secondary sources.

Why farmers in Tikurso catchment were not growing trees

Constraint	Importance (%)
Shortage of potted seedlings	14
Lack of seedlings of the type farmers prefer	13
Land tenure	13
Conflict with other crops	12
Land shortage	11
Tree tenure	11
Protection from livestock	7
Length of time trees and shrubs take before producing	7
Government tax	6
Labour shortage	6
Total	**100**

Farmer's desires, problems and possible solutions identified through discussions in Tikurso catchment

Production desires	Problems	Possible solutions and compromises
Maximize area of crop land	Steep slopes Shallow soils	Use local technologies to manage slopes Grow crops or use technologies on slightly steeper slopes or shallower soils than recommended
Maximize short-term income	Long wait for trees to produce Feed shortage for livestock keeping Lack of capital	Introduce quick-yielding shrubs that produce a sellable product Plant lines of fodder shrubs and grass on bunds Seek credit, or organize an *equb* (a merry-go-round credit group)
Increase yields	Shallow, infertile soils Erosion	Use mulching and composting Plant shrubs to conserve soil Strengthen cutoff drains and build terraces
Grow trees to produce wood for sale	Trees compete with crops Ownership of trees unclear	Plant tree species that do not compete with crops Clarify tree ownership and user rights
Increase amount of feed	Lack of know-how Shortage of seed Shortage of grazing land	Demonstrate improved feed production methods Plant trees and shrubs as a feed source

Development agents can use participatory appraisal techniques to learn about the local community, and to help local people to identify their problems and plan solutions.

Selected constraints and possible modifications to local land-management technologies, identified by farmers in Tikurso catchment

Local technology	Associated problems	Modifications
Stone terrace	Terraces have gaps and are not aligned properly	Train farmers how to align terraces Provide A-frames
	Terraces collapse	Build foundations for terrace risers
		Plant commercial shrubs along the upper side of terrace risers
	Terraces harbour rats	Line with thorny branches to repel rats
	Construction stones are scarce	Plant aloes instead of using stones
Cutoff drains	Farmer groups do not agree on route for drains	Involve elders in extension work, and seek their help in negotiating routes
	Gradient of drains is steep and irregular	Train farmers how to measure gradients. Provide A-frames
	Drains collapse frequently	Improve floor of drains. Plant lower embankments with coarse vegetation
		Plant the underside of drains with shrubs or trees
Manuring	Farmers apply manure before it has decomposed properly	Demonstrate compost preparation

Be cautious about using written questionnaires. People are often suspicious of them, especially if they ask questions about sensitive topics.

It is important to understand how local people make decisions, and the criteria they use to choose what types of crops to grow (and where), which tree or forage species to plant, and what soil and water conservation structures to build. Local people may use very different criteria from outsiders: what is important for the development agent may not be important for farmers, and vice-versa. They also recognize a different set of constraints: a particular technology that appears ideal from a technical point of view may not work because of social, political or economic constraints.

All this means that development agents should not try to impose their own judgements or recommendations. Instead, they should listen to the farmers, and provide advice and options where appropriate and where it helps the farmers fulfil their own aspirations.

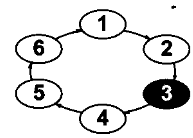
Outcomes

As a result of this stage, development agents and farmers will have analysed:

- The local system of governance and other relevant institutions, and possible ways to improve the land management.
- Local people's desires to increase production, and the constraints they face, in relation to the production potential of the land.
- Their indigenous knowledge and skills, any problems or gaps, and new skills and technologies that might be introduced.
- The criteria and methods farmers use to judge the quality of the land and to select agricultural production and land management options.

The tables on the previous pages illustrate some results of the socioeconomic assessment process in Tikurso catchment, in Tarma-ber *woreda*, North Shoa.

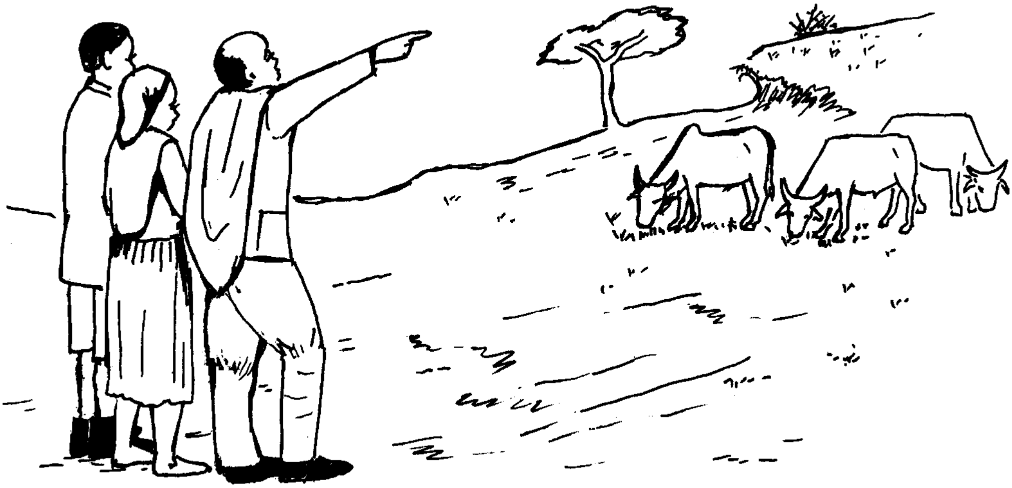
3 Environmental assessment



Environmental assessment goes hand-in-hand with the socioeconomic assessment. The aim is to understand the physical and biological environments, the agricultural system, and their constraints and potentials.

A 'transect walk' is a useful way to get to know the local area. The development agent and a group of local people walk through the community along a line (called a 'transect'). At each location, they note the land use (crops, livestock, forages, trees), the slopes, soil characteristics (type, depth, erosion), water sources, existing conservation measures (terraces, tillage practices, etc.), problems and opportunities.

Farmers have their own ways of classifying land. For example, they may say a piece of land is 'rich' or 'poor', depending on the slope, soil type and fertility, soil depth, drainage, natural vegetation, or a host of other characteristics. It is important to understand these classifications in order to help farmers identify ways the land might be improved.



Local people can draw maps showing the different types of land. The development agent can help them draw maps both of the community as a whole (or part of it, such as a mini-watershed), or of individual farms. These maps, and the transect, can be used to help identify problems, constraints and opportunities. For example, villagers may point out where gullying or flooding occurs, land that might be rehabilitated, possible locations for cutoff drains and terracing, and parcels of land that could be used to plant trees. These improvements can be marked on the map.

See *Farm planning* on page 29 for ideas on how to help individual farmers plan their farms.

Development agents can also help farmers understand the relationships among their farm enterprises: the various types of crops and livestock, forage crops, trees, common land, and other resources. They can draw diagrams to show these relationships.

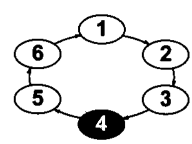
The development agent's agricultural training comes in useful here too. He or she can suggest ways that farmers might improve their crop or livestock yields, for example by using compost or by rotational grazing. This book has many examples of technology options that might be useful.

Outcomes

As a result of this stage, the farmers and development agents will have developed:

- Sketch maps of the area, showing the location and alignments of natural resources and of roads, footpaths, springs, waterways, drains, nursery sites, etc.
- A list of land-management measures to be implemented by the community as a whole, by interest groups, and by individuals on their own farms.
- Criteria for forming groups and mobilizing resources and inputs.
- A list of what issues to deal with at the community, group and individual levels (see *Working with groups* on page 37).

4 Planning



Prioritizing problems

It is unrealistic for local people to try to solve all their problems at once. The development agent helps them identify priority problems they can solve quickly and easily. Once they have achieved an initial target, they will feel confident enough to tackle larger problems. The development agent should facilitate the discussion and decision-making. He or she might make suggestions, but should avoid manipulating the discussion in a certain direction.

Identifying solutions

Once they have identified the problems they want to tackle, the farmers can try to identify solutions. The development agent can help here too (see also the table on page 22).

Training and demonstrations

As far as possible, the development agent should draw on the knowledge and skills local people already have – their 'indigenous knowledge'. But that may not be enough. The agent should also be ready to introduce new technologies to solve specific problems. The following techniques may be useful:

- Persuading an individual farmer or a group to **try out a new technology** on a small scale on their land. This can then be used as a demonstration for other farmers to see, ask questions, copy and adapt.
- Organizing **visits** by farmers to neighbouring areas to see how other farmers have dealt with similar problems. Discussions with the other farmers can be particularly useful. Visits to research institutes or demonstration projects can also help introduce farmers to new ideas.
- Holding informal **training** sessions on specific subjects, such as how to plant elephant grass or how to use an A-frame. This training should be as practical and hands-on as possible. The development agent should avoid lecturing, but should encourage farmers to ask questions (and if possible to work out the answers themselves).
- Using **visual aids** and simple printed materials to help communicate new information.
- Organizing **tests** of technologies to help farmers evaluate them. For example, a farmer might plant a small plot of a new forage grass next to an existing plot, then compare the fodder yield. Farmers may suggest their own adaptations of existing technologies that they can test. See the section on *Monitoring and evaluation* (page 27) for more ideas on how to measure outputs.

- By suggesting solutions based on his or her training and experience, or on the ideas in this book.
- By linking the farmers with outsiders who have the required skills and expertise (such as researchers or other development agents).
- By arranging visits by groups of farmers so they can see how other farmers have dealt with a similar problem.
- By helping the farmers test a new technology on a small scale so they can see if it is relevant to their needs.

Planning

It is now time to plan what to do. Farmers may decide to undertake certain activities as a group – for example, to build a checkdam, rehabilitate a gully, or plant a community woodlot. Or they may decide to do things individually – for example, planting live fences along the edges of their fields, or developing a forage plot to feed livestock using cut-and-carry.

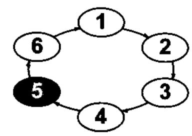
Dreaming is easy, but planning is harder. Plans should indicate what work is to be done, who will do it, when it will be done, and where the inputs (seed, tools, cement) will come from. It is not up to the development agent to decide this: the local people themselves should decide.

Outcomes

The planning stage will result in:

- Detailed, farmer-approved plans for the community or catchment (a community plan), interest groups (group plans), and individual farmers (farm plans). Where appropriate, these plans may include maps, for example to show where conservation structures are to be built or woodlots planted.
- A list of technologies to be used – both indigenous and introduced.
- A working calendar showing when the activities will be done.
- Feasible production targets for each field, set of terraces or forage plot.

5 Implementation

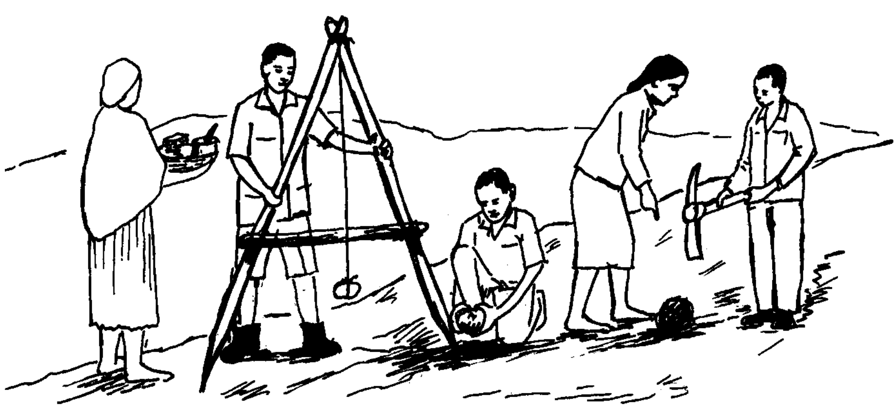


Planning is hard, but implementation is even harder. This is where people put into action what they have decided on. They form groups, build structures, manage resources, and so on.

The development agent's role is to assist, encourage, motivate, organize, solve problems, and provide technical support. If farmers want to form a special-interest group to undertake a certain activity, the development agent can help this group get established, and can advise it on appropriate measures. He or she should take full advantage of innovative farmers who may be able to lead or provide inspiration to such activities (see *Working with groups* on page 37).

The agent should also check to make sure that land management activities are compatible – that one group's cutoff drain, for example, does not cause erosion on someone else's land. A good way to ensure this is to encourage local people to mark their plans on the community map, and to discuss and resolve potential conflicts.

During implementation, the farmers and development agent should decide how they are going to measure the results of their work (see below under *Monitoring and evaluation*).



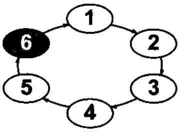
A group of farmers putting their plan into action

Outcomes

The implementation stage will result in:

- Improved land management, higher crop production and greater livestock yields, and ways to measure these.
- Economic benefits, such as greater incomes and improved livelihoods.

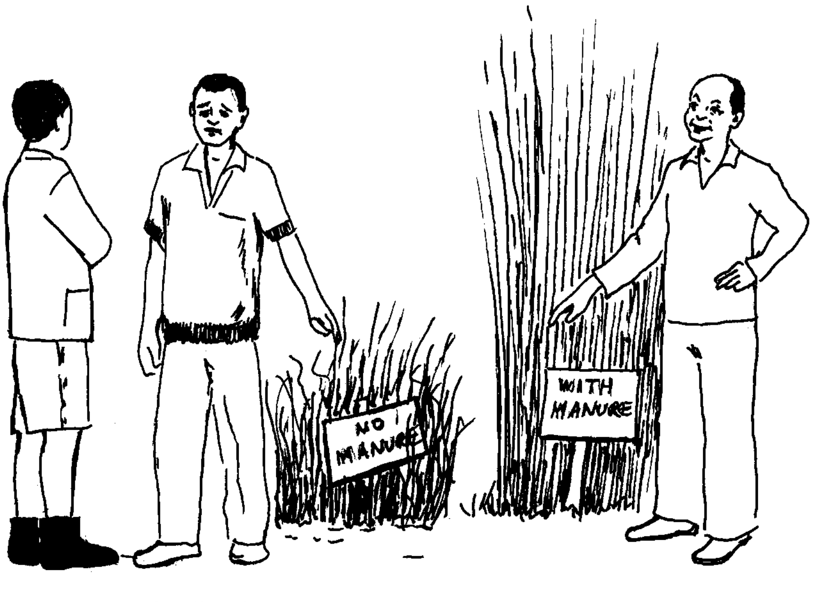
6 Monitoring and evaluation



It is important that both farmers and the development agent monitor activities so they can make adjustments as they go along. At the end of the work, they should evaluate what they have done – and decide on what to do next.

The development agent can help farmers decide how to monitor and evaluate their work. A simple measure of participation is how many group members turn up for work on the specified day. If few people come, there is clearly something wrong, and the group as a whole must take action. Many Ethiopians are already members of various traditional organizations; the management techniques they use might also be useful for land management interest groups.

The group can also think of simple ways to measure progress in terms of controlling soil erosion or increasing soil fertility. They can monitor soil erosion, for example, by driving a metal stick into the ground in a gully. They can measure the amount of erosion (or the amount of soil deposited) by measuring the height of the stick above the ground.



Small-scale tests are a good way to try out new techniques

A good measure of the effectiveness of compost is to compare crops grown with and without compost. A measure of livestock productivity is the number of calves or kids born. And so on.

The development agent should not choose these measures him- or herself, but can encourage the farmers to do so – and to collect the measurements regularly and to analyse them.

The farmers and development agent should meet regularly to discuss the results of these measurements. If they are making progress, they may decide to continue or expand their activities. If the measurements show the activities are not successful, they may decide to adapt them, or discontinue them and try something different.

Outcomes

Monitoring and evaluation results in information that farmers and the development agent can analyse in order to make changes: what was successful and what failed, and ideas on what to do next.

The development agent should also evaluate his or her own activities. What did he or she do right, and what mistakes were made? What caused the problems that occurred? How can things be improved in the future? How can the successes be duplicated so more people benefit? The development agent should discuss problems with his or her subject-matter advisors to identify possible improvements in the future.

Farm planning

Farm planning is an important participatory extension strategy. It helps farmers adopt those crops and technologies that are appropriate to their needs. It also helps translate issues, policies and research findings – which can be difficult for farmers to understand – to the farm level.

Farm planning use a community approach to extension. It assumes that farmers wish to improve their farms. The farmers and their families make their own plans. Development agents or key farmers help them work their way through the process.

Advantages of farm planning

- Planning reduces the risks of new activities.
- It helps farmers to use the time and allocate tasks properly.
- It helps farmers make more money.

Constraints

- Farmers may not understand the benefits of good planning.
- They may not know about appropriate technologies that can help them.
- They may lack information about markets.

The development agent's role

Development agents play an important role in farm planning. They can:

- Train farmers how to plan.
- Help farmers to identify opportunities and appropriate technologies.
- Identify sources of information and provide current information – for example on markets and the weather.
- Give technical assistance on specific topics.
- Encourage farmers to use indigenous knowledge and techniques.
- Identify credit opportunities and advise farmers on the rules and procedures to get loans.
- Assist farmers to implement activities.

Activities that need to be planned

It makes sense to plan new activities like these:

- General farm activities
- Crop improvements
- Conservation measures
- Water harvesting structures
- Livestock expansion
- Improve house
- Purchase new implements
- Social commitments (children's weddings, etc.)

The development agent helps farmers plan

Aspects of a farm plan

Planning can focus on various aspects of the farm:

- **New enterprises or technologies** Cattle production, a woodlot, hiring a tractor, terracing land, etc.
- **The integration of enterprises** Grazing cattle on crop stubble; applying dung on fields, etc.
- **Markets** Where and how to sell produce.
- **Time** When to plant and harvest, what crops to grow, and labour use throughout the year.
- **Land** The use of land for cropping, grazing, forestry, etc., and the siting of soil and water conservation measures.

Enterprises and technologies

Planning a new enterprise (such as cattle raising or a woodlot) or a technology (such as hiring a tractor or terracing a slope) helps the farmer determine how long it will take before an investment pays off and starts being profitable.

Cost-benefit analyses can determine whether a technology is worth investing in. It can also show the price at which the investment would start to give a net income. Cost-benefit analysis compares the total income (the benefits) with the total costs.

To do a cost-benefit analysis of a new enterprise or technology, you need to know:

- The cost of the investments (for long-term payoff).
- The cost of inputs.
- The cost of hired labour (if needed).
- The cost of storing the product, and the possible losses during storage compared with selling immediately.
- The amount of money the farmer can make from selling the produce.

Integration of enterprises

Unlike scientists, farmers do not divide the activities on their farms into different disciplines. All the activities are related, and all are done to benefit the family.

There are three types of flows of biological resources on farms:

- **Recycling of resources within the farm** Farmers use the outputs or waste from one enterprise to support another. For example, they graze cattle on crop stubble, apply dung on fields, make compost from weeds, and feed kitchen waste to chickens.
- **Resources from outside brought into the farm** Farmers bring in inputs from outside the farm: fertilizer, forage, feed, water, etc.
- **Resources that leave the farm** Farmers sell crops and livestock, and erosion washes soil away. These deplete the resource base on the farm. If resources are continually removed from farms without being replaced, the soil fertility and productivity will fall.

On a farm, the biological resources should be recycled as far a possible, so that crop residues, wastes and manures are returned to the soil. This keeps the soil fertile and increases crop yields.

Farmers can choose technologies and enterprises that recycle resources. For example, they may decide to plant a woodlot to produce fuelwood. That means they can use dung as fertilizer rather than burning it, so improving the soil fertility and crop yields.

Markets

Farmers grow trees, crops or raise animals for sale. They try to get a good price for them. There is usually a choice of markets. They can sell produce on the farm itself, at the village market, in a town, or to traders. In towns they may be able to choose between selling to individual households at the market, or through a wholesaler. All these markets have different quality requirements, and fetch different prices depending on the type and quality of the product and the time of year. The prices of products also fluctuate according to weather patterns (rains, droughts).

It may be a good idea to grade produce by quality and to sell it in different markets according to the price. Large amounts of produce are needed for grading to be worthwhile. Farmers can form producer groups to pool their produce for sale. It is also easier and cheaper to transport a large amount of produce than small amounts.

Farmers can get information about markets, prices, amounts and quality through:

- Other farmers.
- Development agents.
- The radio, which every month gives price levels in major towns on various agricultural products.
- Visits to markets.
- Traders (though they may be an unreliable source of information).

Before starting a new enterprise, farmers should collect as much information as possible about it, from all these sources. They should use this information to plan their enterprise, so that the produce is ready when the returns to investment are highest (when the price is highest and the cost is lowest).

Time

Plans can be for one year or more. They may be divided into sub-plans for each season – for example when to plant, when to buy the inputs, when to harvest, what to plant according to the rainfall or water resource available. The plan should take the availability of labour into consideration (there must be enough people to do the work at critical times such as planting and harvesting). It should also consider religious holidays (when labour may be scarce but prices may be high).

Land

All these activities must take place somewhere. Farmers have to allocate land for each type of activity: crop production for home use and for sale, forage production, woodlots, grazing, and so on. They must also decide where to site soil conservation structures, irrigation canals, water storage tanks, house, livestock sheds and ponds.

Factors to consider in farm planning

A number of factors affect planning on a farm. The farmer may not have control over all of them, but it is useful to be aware that they exist. These are:

- Access to credit.
- Availability of inputs (cash, tools, transport, fertilizer, seed).
- Cost of inputs and fluctuations in prices.

8 steps in farm planning

1. The family assesses their problems and needs.
2. They set realistic goals.
3. They decide on a series of activities that will help them fulfil the goals
4. They calculate the costs and benefits of the activities.
5. They plan when to do each activity.
6. They carry out the activities.
7. They check the outcomes and compare them to the initial goals.
8. They analyse why they have reached (or failed to reach) the outputs they hoped.

- Weather.
- Family involvement and needs.
- Taxes.

Access to credit

Credit normally takes the form of loans from a bank or other organization. It may be in cash or in kind (seeds, livestock, fertilizer). It may be granted to individuals or to groups. Access to cash is often a constraint, both when buying inputs for the season's crops and when making larger investments, such as for water structures.

Successful credit schemes are often linked to an initial savings period. People who are able to save in advance will be able to pay back a loan.

Farmers can get credit from:

- Farmers' cooperatives (if they are members).
- Local government credit banks (micro-credit).
- Credit in kind.
- Private or informal sources, such as churches or relatives.

Availability of inputs

Lack of inputs can make planning difficult. Farmers can overcome this by sharing certain inputs. Even though farmers may plan when to buy seed and fertilizer, it may not be available when they need it. If this is likely to happen, the farmers need to be aware of it and plan an alternative. For example, they can keep some seed from the previous crop, exchange seed with other farmers, and keep manure and compost to use instead of fertilizer.

Cost of inputs and price fluctuations

The cost of inputs may vary, as may the price of produce. Sometimes these changes can be predicted. Farmers can explore ways to buy inputs when the price is low. They can also plant and harvest out-of season crops (made possible, for example, by supplementary irrigation) or store crops until the price has risen.

Weather

The amount of rainfall varies each year. Farmers may need to review their plans in view of this. For example, they may decide to plant different crops, or to plant earlier or later than expected. They may also plan for water-harvesting and supplementary irrigation measures.

Family

For the individual farmer, the number of people in the family has an impact on the farm planning. Larger families mean more mouths to feed, and bigger outlays for clothing, education and health. Larger families also mean more hands to do the

Example of how development agents can help farmers plan their farms

Activity	Situation on the farm	How development agent can help
Land allocation	Amount of land for cereal production, vegetables, forages, conservation structures, etc.	Suggest diversifying crops to reduce vulnerability to harvest failure Help farmers calculate what inputs (seed, fertilizer, etc.) are needed Suggest what to plant on conservation structures
Labour distribution	Available labour: husband, wife, children, other relatives, hired labour Usually the chores are divided between the family members in a traditional pattern	Create awareness in gender equity in farm activities Suggest timesaving options, e.g., minimum tillage
Time planning/ activity calendar	Some farming activities (ploughing, planting, weeding, harvesting) are timed according to tradition, not to optimize production	Point out benefits of planting on time Explain which religious holidays are mandatory and which are optional, so are open for working on the farm Give research-based reasons for best times for planting, weeding, harvesting etc. Suggest adequate preparation of implements such as tools and oxen
Capital	Before each expenditure, the farmer needs to know how much cash is at hand, what money is needed for and when and which sources of additional cash are available	Advise on possible sources of cash Inform on which credit institutions are available, and help the farmer to compare their rates
Evaluation of previous year's successes and failures	Evaluating the past year helps in planning the future	Assist with cost-benefit calculations for the last year Assess how bioresources were used Assess natural resources conservation, e.g., if status is degrading or improving
Taxes	Taxes are based on area of land. Other fees must also be paid every year. Farmers need to plan how to make money available at tax-collection time	Offer ideas how to prepare money for taxes without having to sell the harvest when prices are lowest

Continued on next page

Example of how development agents can help farmers plan their farms (continued)

Activity	Situation on the farm	How development agent can help
Social activities	Planning of social events such as marriages, feasts etc., which involve extra expenses	Encourage the farmer to be economical on expenditures Create awareness about family planning needs, e.g., implication of family size on needs and future land allocation within the family
Biological resources	Biological resources available on farms include harvest and crop residues, feed, forage, wood and other tree products, manure, kitchen waste and human waste	Identify what resources exist Suggest techniques to improve sustainability Suggest combinations of resources to maximize their use, e.g., use of different forage combinations
Field crops	Cropping is a major farm activity, so needs a lot of attention from development agents – in terms of the area needed, technology options, fertilizer amounts, land preparation methods, etc.	Identify farmer's training needs Help farmer select the best crop, e.g., to choose between a staple crop and a cash crop Help farmer plan crops dependent on rainfall Calculate costs of fertilizer, seeds and pest management
Conservation	Sustainability of soil and other resources is an issue	Increase awareness on need for conservation Identify tillage methods suitable for the agroclimatic zone and slope Suggest suitable soil conservation structures and species for conservation
Livestock	Aspects include feed, production, animal health and breed	Offer training in feed production: how to grow, what to collect, how to preserve feed for the dry season Suggest suitable forage species and frequency of feeding for increased production Advise on health services Suggest suitable for housing and structures to collect dung and urine. Suggest culling and selection of improved breeds Help calculate feed rations

work. More children means the land will eventually be divided into smaller pieces, making it harder for the next generation to grow enough food.

Different people have different opinions and goals. Men and women, old and young, may have different skills and knowledge. Development agents should try to meet the whole family rather than just one member to ensure that everyone is involved in making decisions, and everyone understands what needs to be done.

Taxes

All farmers have to pay annual taxes immediately after harvest. The government charges a fixed price per unit land area. Many farmers have to grow cash crops to be able to pay these taxes; others have to sell the harvest or animals.

Working with groups

Development agents do a lot of their work with, and through, groups of farmers or other rural people. These groups may be formal or informal, large or small, traditional or 'modern'. The group may already exist, or the development agent may help form it. It may be open to anyone in the community, or just to certain people (women, young people, farmers whose land is irrigated from a particular source of water). The group may have many functions, or it may have only a single purpose. It may be long-lived, or may disband after it has completed its task.

Community, groups or individuals?

Should land management work be undertaken by the community as a whole, by groups of farmers, or by individuals?

Some types of work need to be planned and carried out by the **community** as a whole. These include building footpaths for communal use, rehabilitating large gullies, developing a spring, and setting up livestock exclusion areas. Building these structures may be too much work for an individual or a group, and it benefits the entire community rather than just a few farmers. For some types of land management, it may be best to make plans for a catchment area rather than for an administrative area.

Other types of work may be better handled by **groups** – for example, a group of farmers who cultivate neighbouring plots of land. Examples of this work include digging cutoff drains and waterways, planning and building terraces and contour bunds, and planting woodlots.

Much of the work should be handled by **individuals** on their own land, since they are the ones to benefit. Examples include conservation tillage, planting forage on bunds, planting trees on field boundaries, and managing cut-and-carry feeding of livestock.

There is considerable flexibility in this. The most appropriate level at which to plan and carry out activities depends on the situation. For example, a woodlot can be planted by individuals, by groups, or by the community as a whole. But if an activity is planned and done at the wrong level, people may not feel committed to it, and the effort is doomed to fail. For example, the community should not plan what crops each farmer should grow; this decision is up to each individual farmer.

Working with each level presents particular challenges to the development agent.

- Working at the **community** level may mean dealing with community elders and local governments, who may be reluctant to support the development agents' activities.
- Working at the **group** level may mean helping organize groups and mediating disputes.
- Working with **individuals** is very time-consuming because the development agent must visit each person and discuss his or her individual situation.

Advantages of working with groups

- A group enables people to do things they could not achieve by themselves. For example, a group can get difficult things done quickly, or can overcome labour shortages at a critical time, such as harvesting.
- The group can pool its resources and skills. For example, members of a revolving credit group lend each other money so that one member can buy something she could not afford alone.
- The group can become empowered. The weight of numbers and support of friends may give people confidence to try new things out, challenge the status quo, or pressure for change. Groups can generate a sense of ownership and can help sustain development efforts.
- The group members can share resources equitably and use scarce resources efficiently. For example, they may agree to share irrigation water in a way that avoids conflicts, or buy a lorry to transport produce to market.
- The group may be able to access services that are not open to individuals – such as credit, training, or extension advice. It is impossible for development agents to contact every farmer individually; by working with groups, the agent can serve a much larger number of people.

Disadvantages and constraints

- Development agents may have to serve large numbers of groups, so cannot cater to all of them adequately. (However, this is worse if the development agent must serve individuals.)
- Certain members may undermine the group, or may push for their own interests rather than the common good. If members do not feel the group is serving their needs, they will not participate.
- Establishing and managing groups takes special skills of the development agent and of the group leaders. Building trust and confidence takes time, as does reaching agreements on activities. If the group lacks a common vision, it can be a waste of effort for all.
- Groups that function well for a specific purpose (such as supporting funeral expenses) may not work well in other areas (such as land management). Previously successful groups may fall apart if they are given resources or tasks they cannot manage.
- Development agents may find themselves serving groups without the necessary support from their colleagues and superiors.

Skills required

A development agent who works with groups needs a special set of skills, over and above the range of skills they already need as development agents. These include an ability to form groups and facilitate their management, generate trust and enthusiasm among members, and to plan and monitor activities.

The development agent must be able to:

- Identify and judge the capacity of existing groups, and if necessary organize new groups.
- Identify what the group can (and cannot) accomplish.
- Assess the resources (skills, information, materials) the group members may have, and identify influential members who may be able to introduce new concepts or technologies.
- Organize demonstrations and tests of technologies by group members, or arrange visits to other groups who have tried out a new technology.
- Train members in various skill areas.
- Help the group obtain inputs and build links with other sources of expertise.
- Help the group plan its activities, and monitor, evaluate and report on its work.

Types of groups

A wide variety of groups exist in Ethiopia. Almost everyone belongs to one or more groups. Here are some examples, both traditional and modern.

Debo

A *debo* is a large, traditional, temporary group formed to accomplish a specific task in a given season. Members pool their labour to do work such as building soil conservation structures, cultivated land, harvest crops and thresh grain.

Edir and *equb*

Edirs and *equbs* are traditional organizations whose members support each other economically and socially. They may lend individual members money to buy farm inputs or equipment.

Saving and credit associations

These are modern organizations formed on a voluntary basis to provide financial assistance to members. The members can use credit from the association to buy farm inputs.

Service cooperatives

A service coop is an association of farmers to obtain seeds, fertilizers, equipment and feed. It may also provide marketing services for its members. Service coops often have hundreds of members, and may be part of a wider group of associations.

Grazing land users associations

These are community groups formed to develop and manage pasture in the area.

Water-user associations

Water-user associations include the farmers who rely on a particular irrigation canal or water source (such as a well or tank). The association allocates water among its members and ensures that it is shared fairly, manages the distribution, mediates conflicts among users, and coordinates maintenance. Members may be expected to contribute labour, skills, materials or cash to maintain the water facilities. As with other groups, they formulate rules and impose penalties on members who break them. Both traditional and modern water users groups exist.

Interest groups

Interest groups are farmers who jointly produce one type of commodity, such as potatoes, onion, garlic, or timber from a woodlot. By coming together, they can maximize the cash, labour or other inputs they need. They can also produce enough output to attract merchants who buy the produce. They raise their chances of getting a good price, and maximize their credibility in negotiating and enforcing contracts.

Gender

Women provide more than half of the labour needed for agriculture. They share responsibilities for land preparation, planting, fertilizing, weeding, harvesting, transporting and marketing. They fetch water and firewood. As caretakers of the family, they know which species of trees and shrubs can be used for food and medicine. As caretakers of the animals, they know what plants are best suited as feed. They carry manure onto the fields to maintain soil fertility, or they may use it as fuel.

Women and men typically play different roles in society. These roles can be divided into productive, reproductive, and community activities.

- **Productive activities** These are activities that produce food or earn money that supports the family. Examples are farm work, livestock herding, making handicrafts, selling produce, and doing a job to earn wages. Productive activities are usually shared between women and men.
- **Reproductive activities** These include bearing and rearing children, managing the household, cooking, cleaning, washing, fetching water, and caring for the sick and elderly. Women are responsible for most of these activities.
- **Community activities** These include attending community meetings and religious celebrations, socializing, exchanging news with neighbours, and work on community projects such as building a school. These activities are normally shared between men and women.

Access and control

Although women do much of the work, they are not always responsible for making decisions.

If a woman has **access** to a resource, she can use it but may not own it, and then cannot make any decisions regarding it. For example, she may cultivate land, but may not a have the authority to rent or lease it.

Control of a resource means having both access and the authority to make decisions about it. Ethiopian law gives men and women equal rights of ownership. Land is normally registered in the name of the household head. In case of divorce, or if the land is leased, the wife has an equal say with her husband.

Integrating gender into land management

Gender issues are important at all stages of land management activities. They should be considered not in isolation, but as an integral part of each stage in the development process: in needs assessment, planning, implementation, monitoring and evaluation of land management activities.

When considering gender, do not just look at the different needs and roles of man and women. Also consider children and the elderly. They are also important members of society, though their contribution is often forgotten.

Do not forget other groupings in society: rich and poor, different ethnic groups and religions, people with disabilities or with different levels of education. It is possible to adapt many of the points below to check on their needs and roles. Just replace 'men and women' with 'children and the elderly', 'people with disabilities', etc.

Needs assessment

Identify the different needs and roles of men and women (and children, the elderly, rich and poor, different ethnic groups...) in the community. This will help determine the role of each one in land management activities. During the needs assessment:

- Discover which resources are available in the community, and who has access and control over them.
- Find out who makes various decisions in the community, and how. This will help you approach the right people for each decision.

- Identify the different preferences of men, women and children. Men and women may prefer to plant different crops, tree or fodder species. For example, men often plant crops that they can sell at a high price in the market. Women may prefer to plant nutritious crops to feed the family.

Planning

During the planning stage of land management projects, men and women should be equally represented. Encourage all members of the community to be involved in making decisions – not just providing information or agreeing to what is proposed.

- Try to create an atmosphere that encourages women and children to participate in planning. That means forming the right groupings for discussions. Find out when in the year and at what times of day women, men and children can attend meetings or do land management work.
- Help the community develop a plan based on the needs of the different members of the community – not just of the men.
- Try to anticipate the negative impacts of a proposed activity on men, women and children. For example, making compost may improve soil fertility but may overburden women with additional work.

Implementation

- If women are members of a group, try to make sure that there are equal numbers of men and women in the group. If women are not free to participate in a mixed group, help them form women-only groups.
- Often women farmers do not have access to farm inputs such as seeds, fertilizers, tools, credit and information. However, women may have control over certain types of outputs. Women typically manage milk, butter, cheese and other dairy products, even though men manage the livestock. Work to remove the obstacles hindering women from accessing inputs, and ensure that women get the necessary inputs on time and in the amounts needed.
- Women typically have more demands on their time than men. Schedule activities such as meetings and work so that women can take part and contribute.

Checklists for women's activities

'Productive' activities

- What are the sources of income for women?
- Who controls that income, and what do they do with it?
- What formal employment opportunities are there for women in the area?
- How much are women paid for certain jobs? How does their pay compare with that of men with similar skills and experience?
- What opportunities do women have to enhance their skills through training?
- What activities can women not take part in for cultural reasons?
- Do women have access to loans to expand their businesses?

'Reproductive' activities

- What is the workload of women in the chain of agricultural activities: soil preparation, planting, weeding, fertilizing, processing, packaging, transporting, marketing of various crops?
- How much time is spent on each activity?
- How are tasks shared in the household?
- What cultural norms may exclude men and women from doing certain tasks?
- What tasks are shared by both men and women?
- How much time do women spend in non-agricultural activities such as child rearing and taking care of young animals?
- How far do women have to go to fetch firewood and water? How much time does this take?
- What effect will a new activity have on the time and work women must contribute?

'Community' activities

- What type of community roles do women play?
- How much time do they spend on these activities?
- What community groups and associations do women belong to?
- What material and non-material benefits do they derive from their community roles?
- What type of participation do women have in community activities?
- How do these activities compete with the other roles women have?

Monitoring and evaluation

Monitoring involves gathering and analysing information as an activity is happening, so as to make adjustments. Evaluation means checking the impact of the activity after it is completed. In both monitoring and evaluation, data should be gathered on men and women separately, so that they can be compared. Collect information that ensures:

- Men and women are involved in all activities – both in planning and implementing new activities, and in maintaining existing ones.
- Both men and women participate in management and decision making.
- Benefits are equitably distributed to both men and women.
- Project activities meet the needs of men, women and children.
- Projects do not produce unintended negative effects, such as additional workload, on women and girls.
- Men and women have equitable access to essential inputs.
- The extra time needed to contribute to the activity does not affect the other responsibilities women have.
- The activity improves women's access to and control over resources.

A woman innovator in land management

Land is scarce in Ankober, 180 kilometres north of Addis Ababa. The slopes are steep and the soils erode easily. Farmers in this area use stones to build terraces to hold the soil in place. On the steeper slopes, the terraces are like staircases, with vertical stone risers separating level soil planted with crops. Some of the risers are several metres high and are built with massive stones.

On the gentler slopes, the walls rise above the level of the soil on both sides, trapping silt and water on the upslope side and gradually building up the level of soil.

Ankober is also home to Ayelech Fikre, who experiments with ways to conserve soil and water on her one-hectare farm. Ayelech works hard. She grows cereals, vegetables, root and tuber crops, coffee, forage and pasture crops on the land she inherited from her father 35 years ago. She also has three cows, an ox, a donkey and a few chickens.

Ayelech has introduced three important innovations to the traditional terraces. During heavy rain, pools of water usually form behind the retaining walls, causing waterlogging and killing crops. She made small tunnels in the walls to allow water to flow through to the flat terrace down slope, and then dug furrows to distribute the water throughout the terrace, allowing it to percolate into the soil.

She diverted any surplus water into pits, instead of allowing it to flow away into the river. During dry spells, she uses the water in these pits to water her crops.

Ayelech's third innovation is to build a smaller riser against the main terrace wall, to help strengthen it. The small riser is known as a *mechat*, or 'smaller one'.

Ayelech plants trees and grasses below the risers to stabilize them. She grows maize, millet, beans, tef, ginger and chillies on the terraces. She uses beans and tef to cover the soil surface and protect it from the rain. To maintain the soil fertility, she rotates cereals with legumes: sorghum with soybean, and maize with horsebean.

She also puts the dung from her animals into a pit, along with any spoiled feed and uses the resulting compost as fertilizer on her fields.

The local agriculture bureau has used her farm for demonstrations for the last two years to train other farmers about techniques to conserve soil and water. In 1997 she received an award from the Food and Agriculture Organization of the United Nations for her training work in conservation methods. This remarkable woman is an inspiration to both men and women in her community and throughout the country.

HIV/AIDS

Agriculture is the largest sector in Ethiopia's economy, employs the most people and has the largest production base. Ethiopia is dependent on agricultural exports for foreign exchange to buy essential imports and for development. HIV is a virus, passed on mainly via unprotected sex and unclean needles, which may lead to the deadly disease AIDS. HIV/AIDS seriously reduces the labour force, with several negative effects on agriculture and land management.

Cost of coping

Rural communities have been forced to adopt different coping mechanisms to deal with the problem. Young people – the most productive and skilled part of the labour force – are most affected by HIV/AIDS. The remaining people, often mainly women and children, shift to subsistence farming instead of growing for the market. This reduces household incomes, leading to limited investment in land improvements such as soil conservation and irrigation. Families are forced to sell assets to pay for expensive patient care.

Cost of lost labour

Deaths caused by AIDS mean fewer people working. The cost of labour increases, so overall production costs increase as well. The children and the elderly left behind cannot contribute much to land management. They may not even be able to take care of themselves properly.

What a development agent can do

A development agent is in daily contact with the people. Here are some ways to help reduce the spread of HIV/AIDS and limit the impact of the disease:

- **Create awareness** and provide information about the disease. Many rural communities have beliefs and taboos related to HIV/AIDS, making efforts to control it difficult. Try to be a source of quality, accurate information for these people.
- **Integrate HIV/AIDS issues** in agriculture and land management. The disease harms all sectors of development. Try to incorporate HIV/AIDS issues into planning, implementation and evaluation of all development activities. This is best done by working with health and other agents in the area.
- **Link vulnerable groups** with outside sources. Most rural communities are isolated from services, information sources and other support systems. Link vulnerable groups with support systems outside the community. These groups may be

donors or provide services such as care for orphans, counselling or HIV testing.

- **Promote education on HIV/AIDS** in collaboration with health agents or other relevant individuals. Possible activities include forming community drama groups, running youth clubs, and developing school programmes.

The ABC to avoid AIDS

A Abstain

B Be faithful

C Use a condom

- **Integrate gender concerns** in HIV/AIDS education. Help reduce harmful traditional practices that contribute to the spread of the disease, especially for women.
- **Engage infected people** in agricultural, social and other economic activities to remove the stigma related to having the virus.
- Encourage community members to **use protective measures**.
- **Organize forums** with government and non-government institutions where the whole community can openly discuss the issue, so increasing the level of awareness.
- **Set an example** by protecting yourself against HIV infection, or by living positively with the disease.

If one person in the family is infected by HIV, it can drag the whole family deep into poverty. Here, the husband is infected by AIDS, forcing his wife to sell property to pay for bills. She, too, soon succumbs to the disease, leaving the grandmother and children destitute.

Drought management

Drought occurs when there is not enough rainfall to support crop and animal production. This apparently simple definition conceals a rather more complex reality.

- **Meteorological drought** This occurs when there is rainfall scarcity. Farmers cannot do much to overcome this in the short term: they cannot make it rain more.
- **Hydrological drought** This is when the shortage of rainfall causes a shortage of ground and surface water. Farmers **can** do something about this. They can store water in dams and ponds, and they can use water conservation methods (such as conservation tillage) to increase the amount of water that seeps into the soil.
- **Agricultural drought** This is when there is not sufficient moisture in the soil for crop and animal production. Farmers can do something about this too. They can irrigate crops. They can plant drought-tolerant crop varieties. They can switch from crops to livestock production, or switch to livestock species that use less water. They can avoid drought by planting crops that mature early, or by migrating to other areas (pastoralists frequently do this).

Drought harms many aspects of the agricultural production system: the ecosystem of the area, its hydrology and water resources, agriculture and food security, and human settlement and health.

Causes of drought

Meteorological drought is caused by long-term global environmental changes, or by short-term fluctuations such as El Niño.

The most immediate cause of hydrological and agricultural drought is meteorological drought – a lack of rain. But there are other, human-induced, causes:

- **Environmental degradation** and misuse of natural resources such as forest, land and water.
- **Inappropriate farming practices** – e.g., trying to grow crops in areas better suited to livestock or trees, or using cultivation techniques that encourage runoff.
- **Inappropriate water development** and use – such as wasteful use of water for irrigation, or siting of wells in the wrong places.
- **Rising populations** of people and animals, meaning more water is needed than is reliably available.
- **Inappropriate utilization of human resources** – so people cannot respond to drought in appropriate ways.
- **Weak enforcement of laws** or a lack of regulations governing land abuse – for example, illegal fencing of pastoral land, forcing pastoralists into drier areas.

Stages of drought

Droughts are inevitable in dryland areas. They may occur frequently or less frequently, depending on the location, and rainfall patterns and trends – but they are bound to occur. A drought cycle consists of four stages: **Normal**, **Alert** (or Alarm), **Emergency** and **Recovery**.

Normal stage

Rainfall is adequate, and there are no major problems. But the danger of drought is always present, and one should prepare for it. **Mitigation** measures during this stage include:

- Intensive soil and water conservation measures.
- Spring development and other water harvesting measures.
- Planting a range of crops to take advantage of the available soil moisture and to bridge the gaps between harvests. Plant different crops at different times in mixed cropping or intercropped in the same field to make sure that at least some of the crops can benefit from any rain that does fall.
- Invest in irrigation development.
- Store seeds in case the rains fail.
- Build up social networks so that people can help each other during times of trouble.
- Look for off-farm work, and make and sell handicrafts such as ropes and mats.
- Vary the composition of herds – cattle, sheep, donkeys, goats – to benefit from all the grazing resources available.

Alert or alarm stage

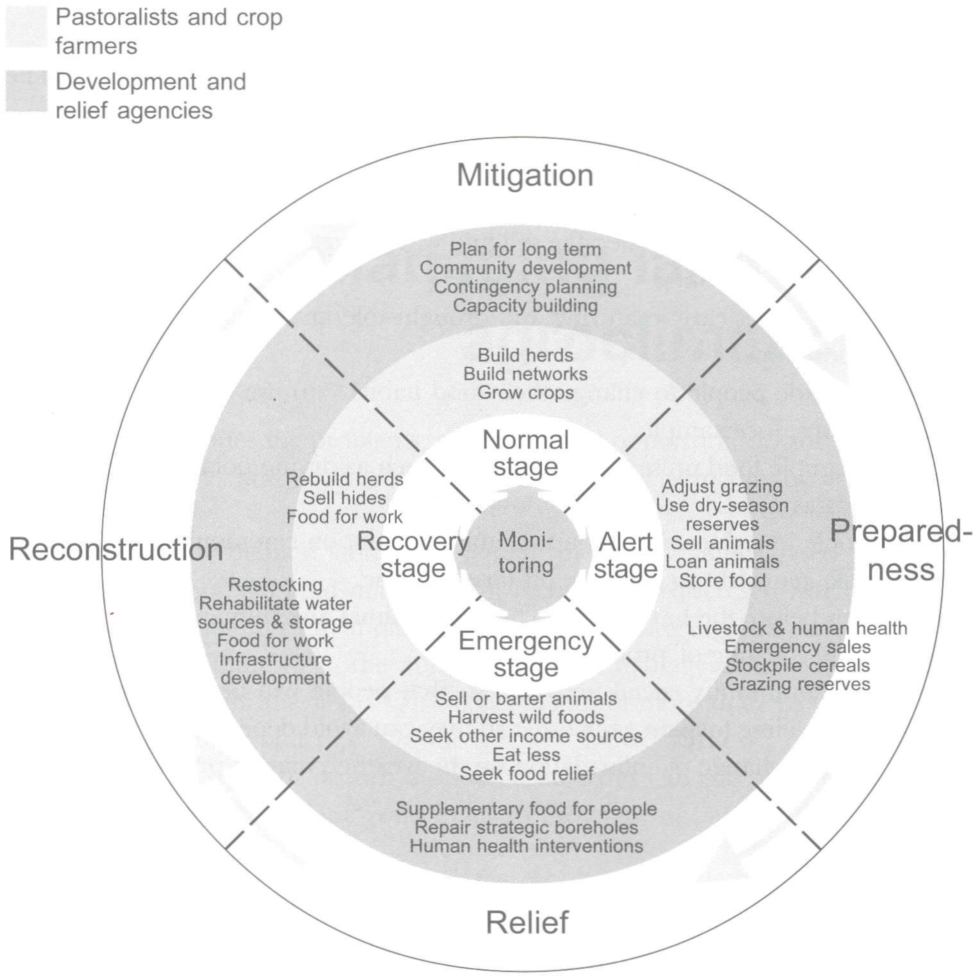
The rain fails and the early signs of drought appear. During this time, **preparedness** measures should focus on:

- Use drought-tolerant or early maturing crop varieties or species such as tef, sorghum, millet, pigeonpeas, vetch, barley, and haricot beans.
- Store and use farm crops economically after the harvest instead of selling them immediately. Sell sheep, goats and chickens.
- Use water harvesting and moisture-conserving techniques.
- Move herds to more distant areas where feed is available.
- Prepare dried meat which can keep for up to 6 months.
- Look for temporary jobs to supplement income.

Emergency stage

Food and water run short, causing severe malnutrition and a large number of deaths among people and livestock. **Relief** measures during this stage include:

- Skip meals and reduce the amount of food in each meal.
- Harvest wild foods and fruits.



The drought management cycle

- Sell animals that are in good condition.
- Exchange livestock and other items for food.
- Appeal on time to the government for help.

Recovery stage

The rains return, and people and animals can begin to recover. During this stage, **reconstruction** activities should be carried on.

- Plant early maturing crops.
- Rehabilitate reservoirs, wells and water storage structures.
- Obtain credit.
- Share labour and other resources with other farmers.
- Build up livestock herds.

What a development agent can do

The development agent can help farmers at each stage of the drought cycle. The particular activities will depend on the location, the type of farmers (crop farmers or pastoralists), and the stage of the drought. Here are some ways development agents can help farmers prepare for drought:

- Mobilize communities to undertake soil and water conservation, afforestation and water-harvesting activities.
- Help farmers select early maturing and drought-tolerant cereals, forages, vegetables and root crops.
- Try to persuade people to change their food habits – to use different vegetables and root crops, for example.
- Introduce simple food preservation methods, such as drying potatoes, sweet potatoes and cassava.
- Advise people to reduce the amount of money spent on ceremonies.
- Help people get credit to generate off-farm income.
- Assess crops before the harvest, and check for animal and human diseases to provide an early warning of problems.
- Strengthen community social networks so that people will be prepared for the drought and willing to assist each other so they can avoid dependency on food aid.
- Facilitate the exchange of information on the weather, market prices, etc.

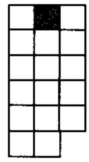
3

Managing land in each agroclimatic zone

This chapter outlines the problems, potentials and opportunities, and the land management measures and options for each of the major agroclimatic zones in Ethiopia.

It gives broadly defined land management measures mainly based on slope and soil depth regimes. All land management technologies discussed in chapters 4 to 9 give richer information for application in the respective agroclimatic zones.

On slopes less than 45%, the appropriate land management techniques depend on soil depth and on the slope. On steeper slopes of more than 45%, the soil depth plays the most important role. On the steepest slopes, with over 60% gradient, it is best not to grow crops or disturb the soil because this can aggravate erosion. For the location of each agroclimatic zone, refer to the map on pages 8 to 9.



Moist Alpine Wurch

Altitude Over 3700 m above sea level
Rainfall 900–1400 mm

The Moist Alpine Wurch has a cold climate, which is sometimes called "Afro-Alpine". Most areas lie above the treeline. The vegetation is dominated by grasses, leguminous herbs and low-growing shrubs. There is no farming because of the high daily temperature fluctuations, regular frosts at night, occasional snowfall, and strong winds. The Moist Alpine Wurch is found only in the Simien Mountains (North Gondar), the Chilalo Mountain in Arsi, and the Batu area in Bale zone.

Problems

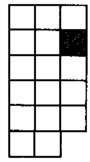
- The cold climate limits the growth of plants and makes the area unsuited for farming – except for livestock grazing, forage production and eco tourism.
- Very few species can be recommended for land management in this zone.
- A lot of wood is needed for heating and cooking, but little is available because the area is above the treeline.

Potentials and opportunities

- The potential for ecotourism is high. The zone is home to endemic wildlife such as the Abyssinian wolf, Walia ibex and Chilada baboon, as well as peculiar giant lobelias.
- Sheep can be raised for wool production.
- High feed-value grasses and clovers make meat from animals raised here tasty.
- Bee forage is available all year round from clover, lobelia, and other herbs and shrubs. Honey from this zone is famed for its taste and fetches high prices.

Land management measures and options

- The best land management is to protect the vegetation from destruction.



Wet Wurch

Altitude 3200–3700 m
Rainfall more than 1400 mm a year

The Wet Wurch has a sub-alpine climate with occasional frost at night. The land is used for livestock grazing and has over the years been exploited for fuelwood collection. Cropping is mainly limited to barley, Irish potatoes and forages. The Wet Wurch is found in the mountains of Amhara, Southern and Oromiya Regions.

Problems

- Due to the cold climate, this zone is not suited for most annual crops. Very few trees, shrubs, grasses or legumes grow well.
- The soils are generally shallow, and the rainfall is highly erosive. The soil is lost quickly unless the surface is protected. Gully formation is common.
- Wood is needed for heating as well as cooking and lighting. Farmers collect and burn cow dung for heat rather than returning it to the fields.

Potentials and opportunities

- There is good potential for raising livestock, especially sheep and bees.
- Ecotourism has potential. The Gelada baboon and Abyssinian wolf live here, along with giant lobelias.
- Water is not a limiting factor in farming. There are two cropping seasons in a year.
- Higher-altitude trees and shrubs such as *Erica arborea, Eucalyptus viminalis*, *Discopodium penninervium*, *Hypericum* spp. and *Maesa lanceolata* grow well, especially with frost-mitigating measures at the seedling stage.
- Suitable forage grasses and legumes include *Danthonia* spp., *Poa* and *Trifolium repens*. The grasses, clover and *Erica* spp. produce tasty sheep meat and honey.

Land management measures and options

- Plant frost-tolerant varieties of species such as *Ensete ventricosum*, *Erica arborea* and *Eucalyptus viminalis.*
- Farmers know when frost is likely. Ways to minimize damage to nurseries:
  - Select the planting site carefully: choose gentle slopes rather than depressions.
  - Sprinkle water on foliage of high-value seedlings at night.
  - Tie the leaves of enset seedlings (*duqulo* and *funta*) together.
  - Burn trash between nursery beds.
  - Cover nursery beds down to the ground with thick grass.
  - Plant shelterbelts at 45–60° angles to the dominant wind direction.
- Construct cutoff drains to dispose of excess water.
- Do not graze or clear vegetation from steep slopes (steeper than 60%).

Moist Wurch

Altitude 3200–3700 m
Rainfall 900–1400 mm a year

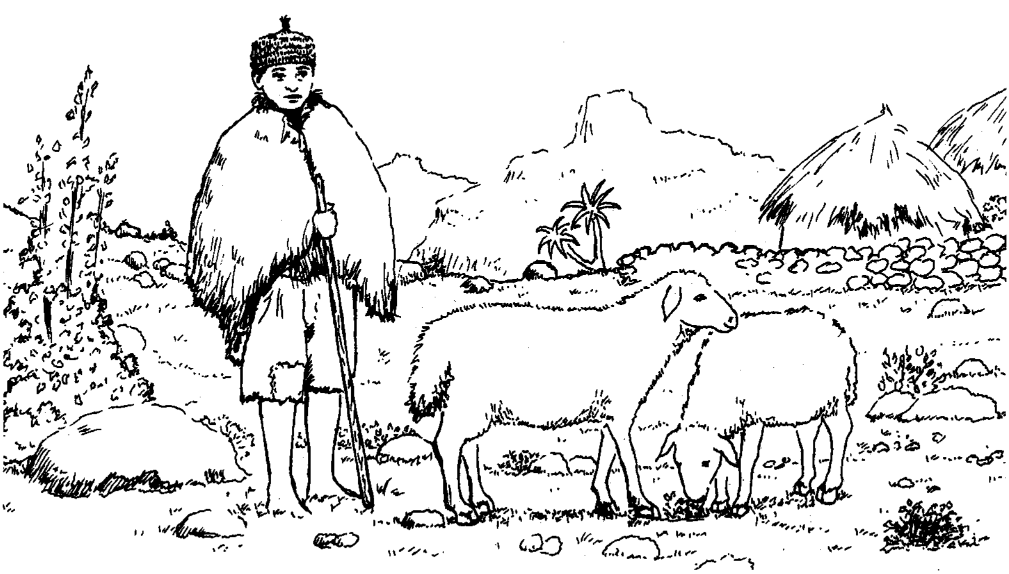
The Moist Wurch is in the highlands of Amhara, Tigray and Oromiya Regions.

Problems

- There is high runoff and soil erosion. The rate of soil loss is very high. Degraded brown soils are common.
- Due to the altitude and harsh climate, few annual crops, trees or shrubs grow here.
- Wood is needed for cooking, heating and lighting.

Potentials and opportunities

- Similar to the Wet Wurch. Barley and potatoes are the only annual crops, with one growing season per year.
- Rainfall is not limiting.
- The soil is generally shallow, though pockets of deeper soil exist on gentle slopes.
- Grasses generally establish well.
- Though they grow slowly, trees and shrubs can be planted. Suitable species include *Arundinaria alpina*, *Buddleja polystachya*, *Croton macrostachyus*, *Dombeya schimperiana*, *Ensete ventricosum* and *Erica arborea.*



Land management measures and options

Crops are not widely cultivated in this zone, but they are often grown on slopes steeper than 30%. With proper conservation measures, slopes up to 45% can be cropped.

Slopes less than 45%

- **Gentle slopes (less than 5%)** Biological soil conservation measures are sufficient. Use mulch, manure, compost and grass strips.
- **Slopes between 5 and 15%** On sticky clay soils, use biological soil conservation measures and graded terraces. Cutoff drains may also be needed.
- **Slopes between 15 and 45%** Level terraces, with cutoff drains between every 15–20 terraces. Connect the cutoff drains to waterways. Reinforce structures with biological soil conservation measures. For example, use lines of trees to support the terraces, and plant grass on banks.

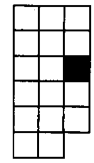
Slopes steeper than 45%

Advise farmers to plant perennials such as fodder crops, fruit trees and shrubs. Do not use terracing, only cutoff drains.

- **Shallow soils (less than 20 cm deep)** Fodder grasses and clovers. Microbasins and pits for planting trees.
- **Soils 20–50 cm deep** Grasses, herbs and shrubs.
- **Soils deeper than 50 cm** Forestry.

Slopes over 60%

- Do not dig or clear vegetation, because this can cause erosion.



Wet Dega

Altitude 2300–3200 m
Rainfall more than 1400 mm a year

Problems

- Soil erosion is severe. There is runoff from cultivated land. Gullies can easily form if the upper catchments are not properly managed.
- Large numbers of sheep and pack animals overgraze grassland.
- Dung is used as fuel because firewood is scarce.

Potentials and opportunities

- Various annual, biannual and perennial crops such as *nug*, beans, wheat, barley, lentils and vetch grow well in this zone.
- Many trees and shrubs grow well. They include *Hagenia abyssinica*, *Juniperus procera*, *Podocarpus falcatus*, *Pouteria adolfi-friedericii*, and *Rhamnus prinoides*. Fruit trees and shrubs, such as peaches, apples and plums also grow well.
- There is enough rainfall to grow crops. Moisture stress is low because of the cool temperatures and high rainfall. Rainfed cropping is possible twice a year. Irrigation could be developed in suitable areas.
- With proper management, it is possible to keep many kinds of livestock.
- There are ample water resources to recharge the groundwater and store water.
- Spring flows can be easily improved.

Land management measures and options

Land management begins with controlling runoff and using conservation measures, starting from the top of the slope and working downhill. It is important to build cutoff drains even if the farmer's field is not at the top of a watershed.

Slopes less than 45%

Where conservation measures are in place, slopes as steep as 45% can be cultivated.

- **Gentle slopes (less than 5%)** Biological soil conservation measures are adequate. Use mulch, manure, compost and grass strips. Prepare compost in heaps rather than pits.
- **Slopes between 5 and 15%** Biological soil conservation measures and graded terraces.

- **Slopes between 15 and 45%** Build graded terraces, interspaced with cutoff drains every 10–15 structures.

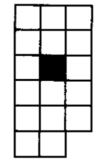
Slopes steeper than 45%

Advise farmers to plant perennials such as fodder crops, fruit trees and shrubs, and to grow commercial trees.

- **Shallow soils (less than 20 cm deep)** Fodder grasses and clovers. Microbasins and pits for planting trees.
- **Soils 20–50 cm deep** Grasses, herbs and shrubs.
- **Soils deeper than 50 cm** Commercial shrubs or trees for timber or poles.

Slopes over 60%

- Discourage terracing. This land is fragile, and any interference may aggravate erosion. Harvest fodder and take it to the animals.



Moist Dega

Altitude 2300–3200 m
Rainfall 900–1400 mm a year

Problems

- The land has been overused for many years, causing widespread degradation. Many areas do not have adequate soil cover.
- The soils are variable.
- Grasslands are often heavily overgrazed, and gullies are common.
- Most dung is used for cooking, heating and lighting.

Potentials and opportunities

- The Moist Dega is good for growing food crops such as barley, wheat and pulses. But there is only one rainy season (no *belg* rains).
- There are ample water resources for various storage options, including groundwater recharging.

Land management measures and options

Slopes less than 45%

Where conservation measures are in place, slopes as steep as 45% can be cultivated.

- **Very shallow soils** Use the area for rearing sheep. This land is not suitable for cultivation.
- **Gentle slopes (less than 5%)** Biological soil conservation measures are adequate. Use mulch, manure, compost and grass strips. Prepare compost in heaps rather than pits.
- **Slopes between 5 and 15%** Especially on sticky clay soils, combine biological soil conservation measures with graded terraces. On silty to sandy soils where water seeps in easily, combine biological soil conservation measures with level terraces and cutoff drains.
- **Slopes between 15 and 45%** Build graded terraces, with cutoff drains every 10–15 terraces. Reinforce the structures with biological soil conservation measures.

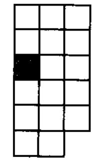
Slopes steeper than 45%

Advise farmers to plant perennials such as fodder crops, fruit trees and shrubs, and to grow commercial trees.

- **Shallow soils (less than 20 cm deep)** Promote fodder grasses and clovers. Microbasins and pits for planting trees.
- **Soils 20–50 cm deep** Grasses, herbs and shrubs.
- **Soils deeper than 50 cm** Commercial trees and shrubs.

Slopes over 60%

- Discourage terracing. This land is fragile, and any interference may aggravate erosion. Harvest fodder and take it to the animals.



Dry Dega

Altitude 2300–3200 m
Rainfall less than 900 mm a year

Dry Dega occurs only in northern Ethiopia (North Wollo and Tigray).

Problems

- Land degradation is widespread. The land has little vegetation cover due to cultivation and grazing over many years. There are more thorny shrubs and bushes than trees. Grasslands are heavily overgrazed, and gullies are common.
- The rainfall is limited and erratic. Occasional heavy rain can destroy level terraces.
- The soils are variable.
- Most dung is used for cooking and lighting.

Potentials and opportunities

- There is less potential evapotranspiration than at lower altitudes (e.g., the Weyna-Dega). Harvesting water by diverting runoff from seasonal rivers and recharging the groundwater table will increase the vegetative cover and protect land from erosion.
- Seasonal cropping can produce highland crops such as wheat, barley, faba beans, lentils and peas.
- There is high potential for rearing livestock, mainly sheep.

Land management measures and options

Despite the low overall rainfall, rains tend to be short and intense. First, take measures to control runoff. Then, between water-disposal structures, promote moisture-retention measures such as level terraces and terraces with tied ridges.

Slopes less than 45%

Measures should aim to harvest moisture, maximize vegetation cover, and increase soil depth.

- Use mulch, manure, compost, grass strips and microcatchments. Promote terraces with tied ridges.
- Combine biological soil conservation measures with level terraces. On silty to sandy

soils where water seeps in easily, combine biological soil conservation measures with level terraces and cutoff drains.

- **Slopes between 15 and 45%** Build graded terraces interspaced with cutoff drains every 20–25 structures. Reinforce the structures with biological soil conservation measures.

Slopes steeper than 45%

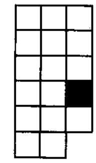
Advise farmers to plant perennials such as fodder crops, fruit trees and shrubs, and to grow commercial trees.

- **Shallow soils (less than 20 cm deep)** Fodder grasses and clovers. Microbasins and pits for planting trees.
- **Soils 20–50 cm deep** Grasses, herbs and shrubs.
- **Soils deeper than 50 cm** Commercial trees and shrubs.

Slopes over 60%

- Discourage terracing. This land is fragile, and any interference may cause landslides. Harvest fodder and take it to the animals.

Wet Weyna-Dega



Altitude 1500–2300 m
Rainfall more than 1400 mm a year

Intensive, diversified farming is characteristic of this zone, mixed with livestock and perennial crops.

Problems

- Severe erosion and land degradation are serious. Gullies are common, especially on degraded grasslands. Terraces may collapse, even on gentle slopes.
- The reddish clay soils typical in this zone are highly acidic and absorb little water.
- Black clay soils are widespread on flat to gentle slopes. They are difficult to manage because of their poor drainage.
- Frequent forest fires destroy the vegetation that protects the soil.

Potentials and opportunities

The Wet Weyna-Dega has the highest agricultural potential of all zones.

- Crops such as barley, beans, enset, lentils, maize, *nug*, tef and wheat grow well.
- Many useful trees and shrubs grow well here. They include *Ehretia cymosa, Grewia ferruginea*, *Juniperus procera*, *Maesa lanceolata*, *Podocarpus falcatus*, *Prunus africana* and *Prunus domestica*.
- Important feed species are *Ehretia cymosa* and *Grewia ferruginea*.
- The reddish-brown clay-loam soils are fairly fertile.
- Grasslands are relatively well established, and trees are common.

Land management measures and options

Land management starts with controlling runoff and treating the land with conservation measures, always starting from the top of the slope and working downhill. After controlling erosion, begin to improve soil fertility between the conservation structures. Use excess water to recharge the groundwater table.

Slopes less than 45%

Where conservation measures are in place, slopes as steep as 45% can be cultivated.

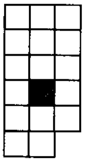
- **Gentle slopes (less than 5%)** Biological soil conservation measures may be adequate. Use mulch, manure, compost and grass strips. Prepare compost in heaps rather than pits.

- **Slopes between 5 and 15%** Combine biological soil conservation measures with graded terraces.
- **Slopes between 15 and 45%** Build graded terraces, with cutoff drains every 10–15 terraces. Connect the cutoff drains to waterways.

Slopes steeper than 45%

Advise farmers to plant perennials such as fodder crops, fruit trees and shrubs, and to grow timber trees. Do not use terracing, only cutoff drains.

- **Shallow soils (less than 20 cm deep)** Fodder grasses and clovers. Microbasins and pits for planting trees.
- **Soils 20–50 cm deep** Grasses, herbs and shrubs.
- **Soils deeper than 50 cm** Commercial trees and shrubs.



Moist Weyna-Dega

Altitude 1500–2300 m
Rainfall 900–1400 mm a year

Agriculture is more intensive here than in the other Weyna-Dega zones.

Problems

- The land is worn out after centuries of heavy use. Slopes are often degraded, with shallow loams and gullying. Terraces may collapse, even on gentle slopes.
- Heavy black soils are difficult to manage.
- Grasslands are choked with poor-quality bushes and low shrubs.
- Forests are reduced to a few areas, though scattered trees are common. Few new trees are planted, and fuelwood is short.
- There is only one rainfed cropping season.

Potentials and opportunities

- The Moist Weyna-Dega is good for food crops such as barley, lentils, maize, tef, wheat. Sorghum is planted less often.
- Enset and *nug* grow in the western highlands.
- This zone is home for many tree species, including *Acacia tortilis, Celtis africana, Ehretia cymosa, Ekebergia capensis, Erythrina abyssinica, Ficus sur, Grewia ferruginea, Hagenia abyssinica, Juniperus procera, Mimusops kummel, Olea europaea africana, Podocarpus falcatus, Pouteria adolfi-friedericii, Prunus africana* and *Rhus natalensis.* Tree planting on farms and along roadsides, and the use of fuel-efficient stoves, could improve the fuel supply situation.
- Livestock production could be improved by planting forage in homeyards.

Land management measures and options

In general, help farmers control runoff and treat their fields, starting from the top of the slope and working downhill. Water harvesting and groundwater recharging could help improve water use.

Slopes less than 45%

Where conservation measures are in place, slopes as steep as 45% can be cultivated.

- **Gentle slopes (less than 5%)** Biological soil conservation measures may be

enough. Use mulch, manure, compost and grass strips. Prepare compost in heaps rather than in pits.

- **Slopes between 5 and 15%** On sticky clay soils, combine biological soil conservation measures with level terraces. Cutoff drains between the terraces may be needed.
- **Slopes between 15 and 45%** Level terraces with cutoff drains between every 15–20 terraces. Connect the cutoff drains to waterways. Reinforce the structures with biological soil conservation measures.

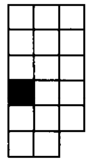
Slopes steeper than 45%

Advise farmers to plant perennials such as fodder crops, fruit trees and shrubs, and to grow timber trees. Do not use terracing, only cutoff drains that if possible lead to underground storage areas.

- **Shallow soils (less than 20 cm deep)** Promote fodder grasses and clovers.
- **Soils 20–50 cm deep** Grasses and shrubs could be grown. Microbasins and pits for planting trees.
- **Soils deeper than 50 cm** Commercial trees and shrubs.

Slopes over 60%

- Soils are very fragile. Digging, terracing and direct grazing cause erosion and landslides. Harvest fodder and take it to the animals.



Dry Weyna-Dega

Altitude 1500–2300 m
Rainfall less than 900 mm a year

Soils are sandy to silty and brownish-yellow. There is little forest left, except for a few scattered remnants. Grasslands are heavily overgrazed.

Problems

- Rainfall is low and erratic, and the rainy season is very short. When it comes, the rain is very heavy.
- Growing sorghum, pulses and maize is unreliable.
- Slopes have very little soil left.
- Growing trees is difficult because of the limited moisture and browsing animals, especially goats.
- Land holdings are small.

Potentials and opportunities

- Soil has accumulated in the valleys.
- The main crops are wheat and barley. Pigeonpea and tef also grow well.

Land management measures and options

Promote water harvesting using ponds and small-scale moisture-retention structures, or by diverting rivers for groundwater recharging where feasible. Level bunds or terraces are recommended. Dig cutoff drains as a precaution, one for every 20–25 level terraces.

Slopes less than 45%

- **Gentle slopes (less than 5%)** Mulching, manuring, composting and grass strips are satisfactory. Make compost in backyards or nurseries, where dead vegetation can be collected easily.
- **Slopes between 5 and 15%** Especially on sticky clay soils, combine biological soil conservation measures with graded terraces. On silty or sandy soils, biological soil conservation measures with level terraces are better. Dig cutoff drains between terraces.
- **Slopes between 15 and 45%** Build level terraces with cutoff drains between every 20–25 terraces. Connect the cutoff drains to waterways. Reinforce the structures with biological soil conservation measures.

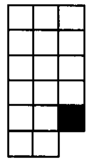
Slopes steeper than 45%

Advise farmers to plant perennials such as fodder crops, fruit trees and shrubs, and to grow timber trees. Do not use terracing, only cutoff drains.

- **Shallow soils (less than 20 cm deep)** Fodder grasses and clovers. Microbasins and pits for planting trees.
- **Soils 20–50 cm deep** Grasses, herbs and shrubs.
- **Soils deeper than 50 cm** Forestry.

Slopes over 60%

- Do not disturb the soil.



Wet Kolla

Altitude 500–1500 m
Rainfall more than 1400 mm a year

This high-rainfall zone is found only in western Ethiopia where there are two long rainy seasons each year. The Tepi area is the best example. It is characterized mainly by perennial cropping – i.e. commercial tree planting and coffee. Trees in this zone include *Albizia grandibracteata, Borassus aethiopum, Coffea arabica* (coffee), *Cyathea manniana, Hevea brasiliensis* (rubber), *Mangifera indica* (mango), *Markhamia lutea, Milicia excelsa, Musa x paradisiaca* (banana) and *Syzygium guineense.*

Problems

- The rainfall is very high and can cause soil erosion and leaching.
- Weed infestation is severe.
- Steep slopes have thin soils, and soil fertility is often low.
- A major problem is waterlogging. Well laid-out drainage structures are needed to dispose of excess water to other sites where groundwater can be recharged.

Potentials and opportunities

- Soils on flat land or gentle slopes are high in organic matter and are fertile.

- The natural vegetation cover is very diverse.
- There is enough water to recharge groundwater and improve spring flows.

Land management measures and options

In general, use water-harvesting and storage measures to bridge the short dry periods.

Slopes less than 45%

Vegetation regrows quickly. Weeds complicate the growing of annual crops. The best option is horticultural crops.

- **Gentle slopes (less than 5%)** Biological soil conservation measures may be adequate. Use mulch, manure, compost and grass strips. Do not use runner grasses such as *Cynodon dactylon* in grass strips or bunds, as they will invade the adjacent fields. Plant Napier grass, Rhodes grass, *Phalaris*, alfalfa or gamba grass (*Andropogon gayanus*).
- **Slopes between 5 and 15%** Biological soil conservation measures combined with graded terraces.
- **Slopes between 15 and 45%** Graded terraces with cutoff drains every 15–20 terraces. Connect the cutoff drains to waterways. Reinforce the structures with biological soil conservation measures.

Slopes steeper than 45%

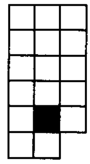
Advise farmers to plant perennials such as fodder crops, fruit trees and shrubs, and to grow timber trees. Do not use terracing, only cutoff drains.

- **Shallow soils (less than 20 cm deep)** Promote fodder grasses and clovers. Microbasins and pits for planting trees.
- **Soils 20–50 cm deep** Grasses, herbs and shrubs.
- **Soils deeper than 50 cm** Commercial trees and shrubs.

Slopes over 60%

- Too fragile for crop production. Collect cut-and-carry fodder during the dry season. In the wet season, controlled grazing is possible.

Moist Kolla



Altitude 500–1500 m
Rainfall 900–1400 mm a year

This zone lies in western Ethiopia. The soils are deeply weathered, yellowish clay loams, heavily leached, with little humus, and silty in texture. In flat areas, the soils may be heavy black clays. Nutrients are held in the vegetation rather than in the soil.

Problems

- The soil is infertile, especially on slopes. Overgrazing and gully formation are common.
- Insects and birds attack crops.
- Farmers use fires to replace tall grasses by short, young growth.
- Drought is a recurrent problem.
- The choice of crops is limited: they include pepper, maize, tef and haricot beans.

Potentials and opportunities

- This area is suitable for sorghum, tef, millet and cotton.
- Farmers are familiar with the benefits of moisture-retaining terrace structures.
- Most areas are suited for grazing. Irrigation can improve pasture quality and the amount of fodder.

Land management measures and options

In general, help farmers to control runoff, starting at the top of the slope. Even when a farmer's fields are not at the top of a slope, it is still best to dig a cutoff drain at the top of the holding to channel excess runoff into a waterway. Measures to harvest water, including river diversion, could make moisture available for longer periods.

Slopes less than 45%

Where conservation measures are in place, slopes as steep as 45% can be cultivated.

- **Gentle slopes (less than 5%)** Biological soil conservation measures may be enough. Use mulch, manure, compost and grass strips. Make compost in heaps rather than in pits. Shading is not necessary.
- **Slopes between 5 and 15%** Especially on sticky clay soils, combine biological soil conservation measures with graded terraces. On silty or sandy soils, it is

better to use biological soil conservation measures with level terraces.

- **Slopes between 15 and 45%** Graded terraces with cutoff drains between every 15–20 terraces. Connect the drains to waterways.

Slopes steeper than 45%

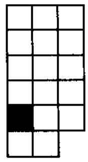
Advise farmers to plant perennials such as fodder crops, fruit trees and shrubs, and to grow timber trees. Avoid terracing. Use stabilized cutoff drains at a spacing of 100–150 m.

- **Shallow soils (less than 20 cm deep)** Fodder grasses and clovers.
- **Soils deeper than 20 cm** Microbasins and pits for planting trees.
- **Soils deeper than 50 cm** Commercial trees and shrubs.

Slopes over 60%

- Ecologically fragile. Avoid digging and overgrazing, which cause soil erosion and landslides. Harvest fodder and take it to the animals.

Dry Kolla



Altitude 500–1500 m
Rainfall less than 900 mm a year

This zone has low rainfall, high evapotranspiration, and is subject to wind erosion. Only species adapted to arid conditions grow here. They include *Azadirachta indica* (neem), *Balanites aegyptiaca*, *Calotropis procera*, *Commiphora africana*, *Dodonaea angustifolia*, *Maytenus arbutifolia*, *Melia azedarach*, *Moringa oleifera*, *Parkinsonia aculeata*, *Pithecellobium dulce*, *Tamarix aphylla*, *Ximenia americana*, and *Ziziphus spina-christi*.

Problems

- Deforestation for charcoal making is widespread.
- Grasslands in many areas are highly degraded and denuded.
- Wind erosion, drought and salinity are common problems.

Potentials and opportunities

- Tef will grow in the short rainy season.
- Sorghum is grown where rainfall is sufficient.
- Soils in the valleys are deeper and more fertile than those on slopes.
- Drought-tolerant tree and fodder species would make more wood and fodder available.
- Livestock production could be improved by reducing livestock numbers, introducing better grazing techniques, and replacing existing animals with more productive breeds.

Land management measures and options

Help farmers to control runoff, starting at the top of the slope. Even when a farmer's fields are not at the top of a slope, it is still best to dig a cutoff drain at the top of the holding and use the excess runoff to recharge the groundwater. Plant crops that tolerate salinity. Store every drop of water in ponds, tanks and underground aquifers.

Slopes less than 45%

Where conservation measures are in place, slopes as steep as 45% can be cultivated.

- **Gentle slopes (less than 5%)** Biological soil conservation measures may be enough. Use mulch, manure, compost and grass strips. Make compost in pits rather than in heaps. Shading is necessary.

- **Slopes between 5 and 15%** Especially on sticky clay soils, combine biological soil conservation measures with graded terraces. On silty or sandy soils, comprehensive biological soil conservation measures with level terraces are better. Cutoff drains are needed between the terraces.
- **Slopes between 15 and 45%** Level terraces with cutoff drains between every 20–25 terraces. Connect the cutoff drains to waterways. Reinforce conservation structures with biological soil conservation measures.

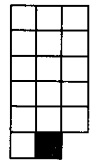
Slopes steeper than 45%

Advise farmers to plant perennials such as fodder crops, fruit trees and shrubs, and to grow timber trees. Do not use terracing, only cutoff drains.

- **Shallow soils (less than 20 cm plough deep)** Promote fodder grasses and legumes.
- **Soils 20–50 cm deep** Grasses, herbs and shrubs can be grown together. Microbasins and pits for planting trees.
- **Soils deeper than 50 cm** Forestry.

Slopes over 60%

- Ecologically fragile. Avoid digging and overgrazing, which cause soil erosion and landslides. Harvest fodder and take it to the animals.



Moist Bereha

Altitude below 500 m
Rainfall 900–1400 mm a year

The Moist Bereha zone is found only in western Ethiopia, in the Gambella region. Due to the low altitude, the climate is hot all through the year. The vegetation is dense, and is composed mainly of tall grasses and trees. The soils are typically deeply weathered silt loams. Flat areas have heavy black clays.

Problems

- This zone is very hot and humid, and working hours are short. Human and animal diseases are common.
- Rainfall is heavy. Waterlogging may be a problem.
- Grasses regrow quickly, and weeds are a problem.
- Soils are susceptible to erosion. Where the vegetation is cleared, the risk of erosion is very high.

Potentials and opportunities

- Plants grow quickly because of the good rainfall and high temperatures.
- Nutrients are held in the vegetation rather than in the soil. Some soils are rich in humus because of the permanent vegetation cover.
- Many types of trees are valued for their edible fruits and medicinal uses. It may be possible to domesticate them.

Land management measures and options

Improve the management of moisture and vegetation, especially of grasses and fruit trees. Use all types of water storage measures to keep water for use during the dry periods.

Slopes less than 45%

Where conservation measures are in place, slopes as steep as 45% can be cultivated. Make compost in heaps rather than in pits. Shading is not necessary.

- **Gentle slopes (less than 5%)** Use biological soil conservation measures, mulch, manure, compost and grass strips.
- **Slopes between 5 and 15%** Especially on sticky clay slopes, combine biological soil conservation measures with graded terraces. On silty or sandy soils where

water seeps in easily, biological soil conservation measures with level terraces are better. Cutoff drains may be needed between the terraces.

- **Slopes between 15 and 45%** Promote graded terraces with cutoff drains between every 10–15 terraces. Connect the cutoff drains to a waterway. Reinforce conservation structures with biological soil conservation measures.

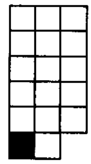
Slopes steeper than 45%

Advise farmers to plant perennials such as fodder crops, fruit trees and shrubs. Do not use terracing, only cutoff drains.

- **Shallow soils (less than 20 cm plough deep)** Fodder grasses and legumes.
- **Soils 20–50 cm deep** Grasses, herbs and shrubs could be grown together. Microbasins and pits for planting the shrubs.
- **Soils deeper than 50 cm** Commercial trees and shrubs.

Slopes over 60%

- Ecologically fragile. Avoid digging and overgrazing, which cause soil erosion and landslides.



Dry Bereha

Altitude below 500 m
Rainfall less than 900 mm a year

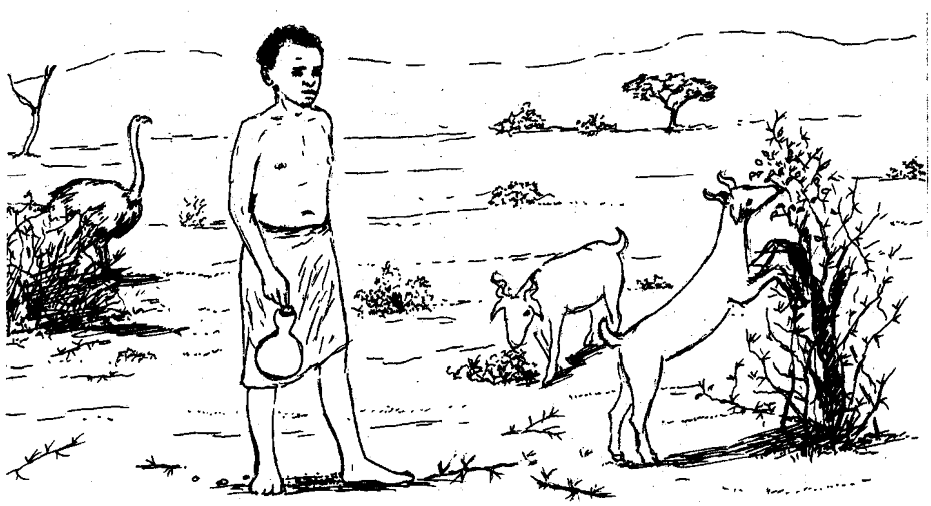
The Dry Bereha zone covers the largest area of all agroclimatic zones in Ethiopia. It is found in the Afar basin in the northeast (part of which is below sea level), the vast Ogaden plains of southeastern Ethiopia, and in northwestern Ethiopia along the Sudanese border. The climate is hot and very dry. The vegetation cover is sparse. Trees and shrubs are thorny and have small leaves. The Dry Bereha is a pastoral area and home to drought-tolerant wildlife. Watering points and shade trees are rare.

Problems

- Temperatures are very high, with arid conditions prevailing, especially in the Dalol Depression, where it is too hot for agriculture.
- Unlike other zones, the Dry Bereha is flat, windswept and prone to wind erosion.
- Where rivers cross the plains, they have deep, narrow banks, making it difficult to divert water for irrigation.
- Infiltration is excessive, and breakage of irrigation canals is a serious problem.
- Rising soil salinity is a major problem.

Potentials and opportunities

- The soils in most of the area (except the Dalol Depression) are alluvial (from flooding rivers) silty, sandy and gravelly loams. The fertility is very good. With water



harvesting and irrigation, crops grow quickly and very well.

- The soil is usually very deep in these alluvial deposition sites and allows deep-rooted trees to grow.
- Where rivers flow nearby or seasonal floods occur, spate (floodwater) irrigation is an opportunity for intensive agriculture.

Land management measures and options

In general, help farmers establish windbreaks at the right shape and orientation.

Slopes less than 45%

Land management is different from other zones because rainfed agriculture is limited to irrigated areas.

- The Dry Bereha is mostly flat or gently sloping. Use moisture harvesting techniques for gentle slopes.
- Where irrigation is practised, plant windbreaks along field boundaries to reduce wind erosion. Apply mulch, manure, or compost, and use grass strips to protect the soil from dryness. It is difficult to get enough material to compost, but cow dung is abundant. Vegetation grows quickly at well-watered nursery sites and around watering points.
- Control salinity with lime.
- Invasive species such as *Prosopis juliflora* are a problem unless they are widely spaced and pruned to form single-stem trees with few branches.
- Water seeps into the soil quickly, sometimes too quickly. To minimize effect of broken canals and to cut infiltration, promote measures that improve the water-holding capacity of the soil.
- In areas where trees and shrubs are cultivated, use structures such as microbasins that retain moisture and catch windblown soil particles.
- **Slopes between 15 and 45%** Build level terraces with widely spaced cutoff drains. Connect the cutoff drains to waterways. Reinforce the structures with biological soil conservation measures.

Slopes steeper than 45%

These slopes are ecologically fragile. Digging, terracing and grazing destroys vegetation and encourages erosion. Avoid disturbing the soil. Set aside land for perennial crops such as fodder crops.

- **Shallow soils (less than 20 cm plough deep)** Fodder grasses, legumes and shrubs. Microbasins and pits for planting trees.
- **Soils 20–50 cm deep** Grasses, herbs and shrubs, together or separately.

4

Managing soil fertility

Soils in Ethiopia range from the very fertile to the very infertile. But even the richest soils can become exhausted after centuries of use. If the soil is inherently poor, extra effort is needed to improve its fertility.

This section describes various methods to maintain and improve soil fertility. It covers multiple cropping, crop rotation, fallows, alley cropping, cover crops and green manures, composting, mulching, and the use of animal manure and chemical fertilizers.

There is a close relationship between soil fertility and soil and water conservation (Chapter 5) and water management (Chapter 6). Many of the techniques described in this chapter also help prevent erosion and conserve moisture. And many of the techniques described in Chapters 5 and 6 contribute to soil fertility by preventing the loss of precious topsoil and helping build up organic matter.

Multiple cropping

'Multiple cropping' means growing two or more crops on the same field in a single year. It increases total production because it optimizes the use of natural resources. Different crops grow at different heights and have different rooting systems, so can exploit the available light, water and nutrients better than a monocrop. They grow at different rates (or are planted at different times), so can use these resources to the full. The box on the next page lists some types of multiple cropping.

Where to use multiple cropping

Agroclimatic zones In principle, multiple cropping can be applied in all agroclimatic zones where agriculture is practised. It is most appropriate in medium-to-high-altitude areas where good rainfall favours the growth of a wide range of crops (Moist and Wet Kolla, Weyna-Dega and Dega). Multiple cropping is less suited to extreme high altitudes or dry lowlands.

Soils Multiple cropping can be adapted to all soil types.

Row intercropping maize with beans. The beans fix nitrogen in the soil for the maize to use.

Advantages of multiple cropping

- Planting crops with different growth habits on the same field at the same time makes more efficient use of soil nutrients. There is less leaching of nutrients because of deeper and denser crop roots.
- Multiple cropping provides better and longer soil cover, reducing erosion.
- If one of the crops is a legume, it fixes nitrogen in the soil that the other crops can use. This is equivalent to a crop rotation (see page 86).
- Growing several crops reduces the impact of crop failure. If one crop fails or is attacked by pests or diseases, the second or third crop often succeeds.
- The higher crop population squeezes out weeds.
- Some crops can repel or trap pests, e.g., cowpeas and 'sticky' desmodium.
- The farm family gets improved nutrition and additional income.

Different kinds of multiple cropping

Intercropping Planting two or more crops in the same field at the same time. Crops can be planted in rows (*row intercropping* – see the picture on the previous page) or broadcast (*mixed intercropping*). Planting in rows makes weeding and harvesting easier. Intercropping increases plant competition (for light, water and nutrients) during all or part of the growth season.

Monocropping Growing only one crop in a field. The opposite of multiple cropping.

Multiple cropping Growing two or more crops in the same field at the same time, or one after the other in the same year. Multiple cropping can be done with annual crops, perennial crops, fodder crops and tree crops.

Multistorey cropping Growing perennial plants and annual crops of different heights simultaneously on the same field. The lower layer may include groundnuts, sweet potatoes, beans, etc. The second layer may include papaya, banana or enset (false banana), etc. The third layer (overstorey) may include mango, avocado, coconut or oilpalm.

Relay cropping Growing two or more crops in a field with their growing seasons overlapping. For example, planting a second crop (tef or cowpeas) in a field where the first crop (maize) is nearing maturity. After the first crop is harvested, the second crop continues to grow.

Sequential cropping Growing two or more crops in the same field in the same year, one after another. Also called double or triple cropping.

Strip cropping Planting alternate strips of grasses or grains with other crops along the contour to conserve moisture and reduce erosion on gentle slopes and unstable soils. Strips should be planted far enough apart to make cultivation easy, but near enough for the crops to interact (e.g., nitrogen fixed by one crop becomes available to the other). The strips can vary from 15 to 45 m wide, depending on the slope and the severity of erosion. Generally, use narrow strips on steep slopes and wider strips on gentle slopes. The crops are cultivated independently of each other.

Multistorey cropping: mango and papaya growing above broadcast maize intercropped with peas and pumpkin. Such high plant population leaves no room for weeds, and protects the soil from erosion.

Disadvantages and constraints

- The crops compete with each other for light, water and nutrients, so they may yield less (per hectare) than if they are grown in a pure stand. However the **combined** yield of all the crops is usually higher than a monocrop.
- Harvesting is more laborious or difficult than for monocrops.
- Controlling weeds with herbicide may not be feasible because the intercrop might be damaged.

What to consider before using multiple cropping

Intercropping should use crops that have different growth habits and nutrient requirements – such as cereals and legumes.

When choosing different crop species, it is important to understand the planting times and how the different crops affect each other. Observe the indigenous methods that farmers already use. Farmers often have excellent knowledge about the crop combinations suited to their needs and agroclimatic zone.

Relay intercropping (where the second crop is planted after the first crop is close to harvest) requires especially good knowledge about which crops are suitable and when to plant them.

Examples of crop combinations

Mixed intercropping

- Tef with safflower or sesame
- Sorghum with pearl millet and cowpea
- Maize with groundnut, brassica crops or pumpkin.

Multistorey cropping

- **Top layer** tall perennial fruit trees (such as mango and avocado)
- **Middle layer** shorter perennial crops (papaya, banana, cassava)
- **Bottom layer** annual crops (maize, sorghum, haricot bean).

Relay intercropping

- Maize with tef, potato or faba bean.

Row intercropping

- Maize with haricot beans, cowpea, pigeonpea or forage legumes
- Sorghum with haricot bean, soybean, groundnut or forage legumes.

Sequential intercropping

- Early maturing tef or barley followed by pigeonpea, lentils or rough peas.

Strip intercropping

- Erosion-susceptible crops such as maize or sorghum, in strips with erosion-preventing crops such as haricot bean, cowpea, pigeonpea, groundnut, mungbean, dolichos or alfalfa.

Acacia albida: The farmer's friend

An excellent example of intercropping is found around Debre Zeit, south of Addis Ababa, where the staple crop tef is grown in fields under the canopy of *Acacia albida*. The tef grows right up to the base of the trees. The trees and crop coexist on the same piece of land at the same time. The trees are leguminous, so add nitrogen from the air to the soil, raising the tef yields.

Acacia albida is a fodder tree, well adapted to dry areas such as the Dry and Moist Weyna-Dega and Kolla. It keeps its leaves throughout the dry season, when other trees are leafless. The leaves can be cut and fed to livestock when grazing is scarce. The protein-rich pods fall to the ground when the rainy season starts.

Acacia albida drops its leaves at the beginning of the rainy season, allowing crops to grow under its bare canopy. The tree has a deep and spreading root system, and is drought-resistant. It grows fast and coppices well. The wood is excellent for fuel and has many other uses.

Crop rotation

Crop rotation means growing different crops in the same field from one year to the next. It maintains and restores soil fertility and controls the buildup of pests.

Farmers might grow cereals in the first season, followed by a legume in the second season, then an oil or a tuber crop in the third season. They can then plant cereals again in the following season. Leguminous crops are especially important in rotations because they fix nitrogen and restore soil fertility.

Crop rotation can be used in all agroclimatic zones where farming is practised, and on all soil types.

Factors influencing crop rotation

The choice of crops depends on many factors. Farmers should consider the following when planning crop rotation:

- **What crops grow well:** depends on the soil fertility and the expected rainfall.
- **The farmers' needs:** including the staple food and the market value of crops.
- **The previous crop:** try to change it, especially if pest attacks were severe.

Advantages of crop rotation

- Crop rotation helps control pests.
- It restores and maintains soil fertility and improves the productivity of the land.
- It provides different sources of income and nutrition.

Disadvantages and constraints

- It may be difficult to rotate crops if there is not enough land to grow the staple crop, or if seeds of other crops are not available.

Examples of crop rotations in different agroclimatic zones

	Year 1	Year 2	Year 3
Dega	Barley	Horsebean, field peas	Wheat, linseed
Weyna-Dega	Wheat, maize	Lentils, pigeonpea, barley	Tef, barley, sorghum, haricot
Kolla	Sorghum, millet	Cowpea, soybean, haricot bean	Tef, maize, sesame

Fallows

A fallow is cropland left uncultivated for one or more years so the soil fertility recovers. The land can be left idle, or it can be sown with grasses or legumes. Legumes also help improve the soil fertility by fixing nitrogen. The fallow land can also be used as pasture, or the vegetation can be cut and carried to feed livestock (see *Cut-and-carry*, page 200).

Fallowing is useful in areas where land is plentiful but the soil fertility is poor. It is becoming less popular in densely populated areas because farmers need the land to grow crops every year.

Where to use fallows

Agroclimatic zones All agroclimatic zones except Dry Bereha, but important at high altitudes (Wurch and Dega).

Soils All soil types.

Slopes Slopes less than 60%.

Advantages of fallows

- Fallowing restores the soil fertility and helps reduce erosion.
- It reduces the incidence and severity of crop pests by breaking their life cycle.
- The fallow land can be a source of livestock feed.

Disadvantages and constraints

- Fallowing takes land out of crop production.
- It can allow weeds and bush to spread.
- Farmers may not see the longer-term benefits of fallowing.

How to manage fallows

1 Fence off the land and sow grass or legume seeds on it. Suitable species include alfalfa, clover, lentils, pigeonpea, sesbania, tree lucerne and vetch.
2 Keep livestock off the land until it is ready for cut-and-carry harvesting, or for grazing.
3 Control aggressive weeds that may compete with the legumes.

Cover crops and green manures

Cover crops are planted to conserve the soil on bare or fallow farmland. They can be grown in fields or between any trees such as avocado, mango, *Acacia senegal* and sisal.

A green manure is a fast-growing legume sown in a field several weeks or months before the main crop is planted. When the legume flowers, it is ploughed into the soil. This increases the organic matter of the soil and increases the ability of the soil to hold moisture.

Tree legumes used as green manures are also called 'fertilizer trees'. They fix nitrogen in the soil and are more permanent than other types of green manure.

Both cover crops and green manures improve soil fertility.

Where to use cover crops and green manures

Agroclimatic zones Moist and Wet Wurch, Dega, Weyna-Dega and Kolla, and Moist Bereha, where there is little or no problem of moisture stress. Cover crops can be used in areas where rainfall is more than 800 mm a year, and where the rains last for more than 5 months.

Soil types All soil types.

Slopes Slopes less than 60%.

Cover crop growing between an orchard crop

Advantages of cover crops and green manures

- Cover crops can be fed to livestock.
- Cover crops use the space between trees productively.
- Both cover crops and green manures protect the soil from wind and rain erosion, and improve the soil fertility.

Disadvantages and constraints

- A cover crop or green manure uses up moisture in the soil. (Balance this against the protection it gives to the soil and the improved soil fertility.)
- Farmers may be unwilling to put in the labour or buy the seed needed.

Suitable crops

A mixture of **forage grasses and legumes** is best. For example:

- Vetch, alfalfa and clover are suitable for areas above 2400 m.
- *Dolichos*, alfalfa, cowpeas and haricot beans are suitable for areas between 1500 and 2400 m.
- Cowpeas, soybeans and mungbeans are suitable for areas below 1500 m.

Here are some examples of suitable **tree legumes**:

- *Chamaecytisus palmensis* (tree lucerne) for highlands above 2000 m.
- *Sesbania sesban* for mid-altitude highlands (1500–2500 m).
- *Gliricidia* spp. for land below 1500 m.

How to grow green manure

1 Sow the green manure seeds during the short rainy season in March/April, about 45–60 days before planting the main crop. This gives them time to grow before the main crop is sown.

2 Plough in the green manure about 2 weeks before planting the main crop, i.e. in June/July.

How to grow a cover crop

1 Sow the cover crop early in the short rainy season, or at the beginning of the main rains.

2 Leave it in the field for as long as required. Cut and feed to livestock as needed.

Compost

Compost is fertilizer made from leaves, weeds, manure, household waste and other organic materials. Farmers can make compost in heaps or in pits, depending on the local climate and the farmers' wishes.

Compost is an excellent soil builder. It supplies a wide variety of plant nutrients. It also creates a favourable environment for soil microorganisms. It improves the ability of the soil to hold water and withstand compaction. These improvements increase crop yields and can last for several seasons.

Where to apply

Agroclimatic zones Virtually all climatic zones. Composting takes longest in the coldest zone (Alpine Wurch). In the Dry Bereha there may be too little moisture to make compost.

Soils All soil types.

Composting works best under warm, moist and well-aerated conditions that allow material to decompose quickly.

Advantages of composting

- Compost is valuable natural fertilizer that contains readily available plant nutrients. It improves the water-holding capacity of the soil. Its helps all crops grow better, and its effects last several cropping seasons.
- Compost recycles organic materials from around the farm and house.
- If done properly, the composting process kills weed seeds, so using compost does not spread weeds.
- There is no financial cost. All farmers, rich and poor, can make compost using materials and tools they already have.

Disadvantages and constraints

- Different types of organic materials are required, such as crop residues and other biodegradable materials. If only one type is available, composting is not practical.
- Composting is difficult in areas where organic materials, farmyard manure and water are scarce.
- A lot of work is needed to make large quantities of good compost. (Get the whole family to help.)
- Compost can have a bad smell if it is not managed well. If there is not enough air in the pile, anaerobic conditions will produce this foul smell. Done properly, compost does not smell bad. (Keep the pile well aerated.)

How to make compost

There are two basic methods of making compost: the **heap** method, and the **pit** method. The only real difference between the two is that the heap is built above the ground, while the other method requires digging a large pit.

The heap is done in an open area, where organic materials can be gathered and perhaps stored until ready to add to the pile. This method is more suitable for high rainfall areas. The heap allows excess water to drain away and avoids waterlogging.

The pit method is better for dry areas (especially in the Bereha) where moisture is limited or windy conditions occur.

You will need:

- Various organic materials: crop residues, farmyard manure, kitchen wastes, urine, etc.
- Tools to dig a pit (for the pit method), a cart, a machete.
- Water, a watering can or other container.
- Topsoil, or mature compost from another batch.
- A 2 m-long, pointed stick, bamboo pole or reed.

1 Select a suitable site, not too close to houses or sources of drinking water. Compost produces a liquid that can contaminate nearby shallow wells or ponds. In dry regions, locate the pit in the shade of a tree if possible, or plant fast-growing trees to provide shade. Make sure the site does not flood during heavy rain.

2 Collect all available organic materials that biodegrade readily. Animal manure and urine, crop residue, grasses, weeds (but not seedy or noxious ones), other plant parts and ash are all good. Animal manure is not essential, but helps. Chop up any coarse vegetation or crop residues with a machete or spread it on a threshing floor where livestock can trample on it.
3 Decide how big to make the pit (or heap) depending upon how much organic material you have. In general the pit can be as wide as needed but the ideal depth is about 50 cm. Heaps may be roughly 2 m wide and 1–1.5 m high. A pit or heap smaller than 1 m^2 is too small.
4 Spread small branches and other coarse materials such as maize or millet stover at the bottom of the pit or heap, to a depth of about 10–15 cm. This helps the air circulate and allows water to drain away (in the wetter zones).
5 Spread different organic material in layers. Make a layer of organic material about 5–15 cm thick, then spread a thin (1–3 cm) layer of soil or ash on top. The thickness of each layer is not as important as using a variety of different materials to give a balance of nutrients in the final compost.
6 Add more layers of organic material, and of soil or ash, until you have used up all the materials you have, or until the pile is high enough (or the pit is full).
7 Push the long, pointed stick (or bamboo pole or reed) at an angle all the way into the heap or pit. This stick is used to check the temperature of the pile as it heats up and cools down. Using a reed or bamboo pole (with the nodes opened up and holes in the side) helps air get into the heap. It also allows you to measure the temperature of the compost better.
8 Cover the heap with dry grasses or crop residues. In cold, highland areas, cover the sides of the heap with soil. This helps keep the temperature inside high and minimizes moisture loss.
9 Let the heap decompose for about 3–5 weeks. During this time the heap or pit contents will get smaller. Pull out the stick to check the temperature of the contents. If they have cooled down, the compost needs turning. Always keep the compost moist. You can throw household washing water on it.
10 When the pile cools down, turn and mix the compost (after about 3 weeks in Kolla and Weyna-Dega zones and about 5 weeks in Dega zones). Repeat the turning and mixing operation once or twice. Compost normally matures in 2–3 months in the Kolla, 3–4 months in the Weyna-Dega, and 3–5 months in the Dega zones.

How and when to apply compost

If they have made a lot of compost, farmers may prefer to spread it on the less fertile areas of their fields. Rather than give a blanket rate which is unrealistic, advise farmers to spread compost where it is most needed (e.g., on high-value crops). Apply compost at time of ploughing: cover the soil with a few centimetres of compost, then plough it under. Never leave freshly spread compost on the surface; dig or plough it in right away. If it is exposed to the sun or rain, valuable nutrients will be lost.

For seed that is planted, such as maize, beans and sorghum, you can apply small quantities of compost directly in the planting holes or furrows.

Materials for making compost

The best plant materials for making compost are those that break down, or decompose, quickly. Vegetation that has dried out completely will take much longer. However, the rate of decomposition depends on the type of materials used, the management practices used, and the local climate.

Avoid making compost from noxious weeds such as striga. Large amounts of eucalyptus leaves will slow down decomposition.

Buying oxen with compost

In the mid-1990s, Ato Gebre, a farmer in the Hashengi valley of southern Tigray, had a problem and was forced to sell his oxen. He then had to sharecrop his land with a neighbour who had oxen. In 1998 he learned about compost, and started using it on his land instead of chemical fertilizer. In 1999/2000 his crop yields were so good he was able to sharecrop and buy an ox. The same happened in 2000/01. Now he is managing his own land himself again, and continues to use compost. Over 90 farmers in the Hashengi valley now make and use compost, either in groups of 10 families, or individually. Some combine the compost with small amounts of chemical fertilizer to boost yields further.

The lesson Used correctly, compost can raise yields significantly and allow farmers to improve their incomes without taking on debt.

Mulch

Mulch is a layer of straw, leaves or other plant materials used to protect the soil surface. Its main purpose is to shield the soil surface from the hot sun and falling rain, minimizing soil crusting, erosion and runoff.

Where to use mulch

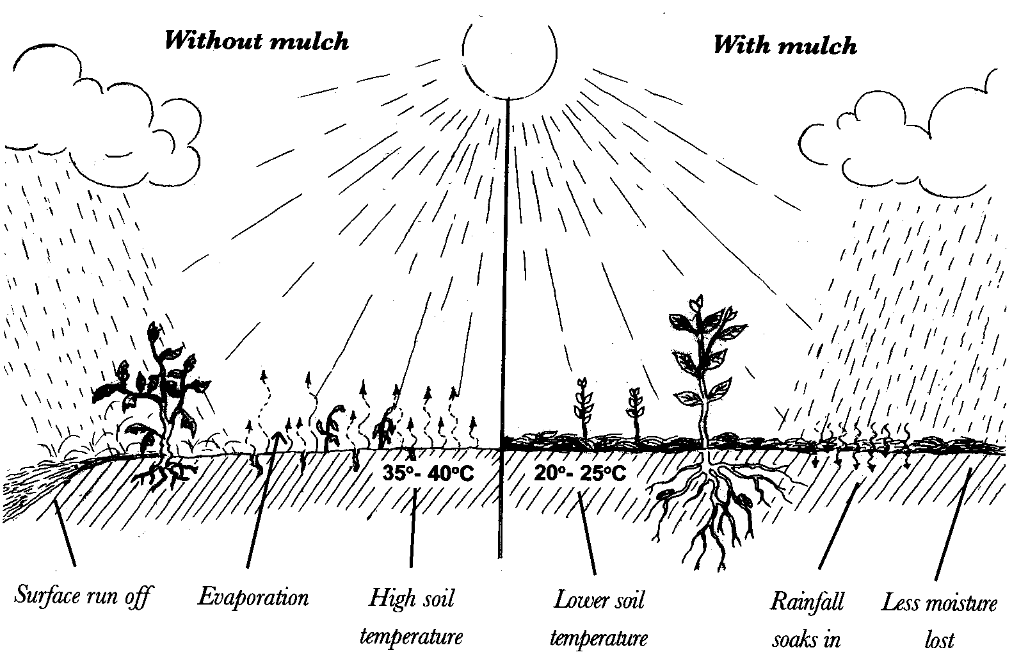
Agroclimatic zones Mulching is suitable for all the Dega, Weyna-Dega and Kolla zones, and in the Moist Bereha. It is not suitable for the Wurch and Alpine Wurch (too cold).

Soils In general, mulching is well-suited to light and well-drained soil types. It is less suited to heavy soils where waterlogging is a problem.

Mulching is of most practical use in row crops such as maize and sorghum, and for widely spaced perennial fruit trees such mango, avocado and citrus.

Advantages of mulching

Mulching creates a favourable environment for soil microorganisms. As the mulch breaks down, it improves the organic matter and nutrient content of the soil. It also suppresses weeds, so helping increase yields.



Mulch encourages rainwater to soak into the soil and reduces the rate of evaporation from the soil surface, so raises the moisture content of the soil. It also reduces the temperature fluctuations in the soil.

Disadvantages and constraints

- Mulching may be difficult in dry areas where crop residues and other organic materials are used as either animal feed or fuel, and in the Wurch and Alpine Wurch where the decomposition rate is too slow.
- Mulch is not suitable for broadcast small-grain crops which have very close spacing.
- It can be a habitat for some pests and fungal diseases.
- If used in very wet conditions and on heavy soils, mulch may aggravate waterlogging.

What to use as mulch

Large amounts of organic materials are needed to get the full benefits of mulching. Any organic debris – straw, weeds removed from fields, prunings from hedgerows – can be used. Avoid crop residues that harbour pests such as maize stalkborer. Where weeds are not used as animal feed, they can be used as mulch.

When to use mulch

- Under conventional tillage, before planting the main crop, plough under the mulch to incorporate it into the soil.
- Under conservation tillage, keep the mulch on the field while the crop is growing so the mulch controls weeds.

Manure

Manure consists of animal dung and urine. It is the best form of organic manure. When added to the soil, it improves or sustains soil fertility, improves the soil texture and structure, and increases its water-holding capacity.

Animal manure contains small amounts of nitrogen, phosphorus and potassium nutrients (see *Inorganic fertilizer*, page 100). Urine contains more nitrogen than solid dung does, and should be collected along with the dung and used as fertilizer. Biogas slurry also makes excellent manure. If manure is scarce, use it to fertilize high-value crops such as vegetables, and in home-gardens.

Manure has many other uses. Farmers dry it and use it as cooking fuel. They mix it with water to make plaster for walls and threshing floors, and to seal pots. They even use urine as a pesticide.

But manure is best used as fertilizer. Farmers who currently use manure as fuel can save it by planting a woodlot so they can produce firewood.

The quality of the manure varies widely. It will be good if:

- The animals are fed with high-quality feed such as legumes and concentrates.
- The manure is kept covered and out of the rain.
- Cattle manure is mixed with manure from other types of animals, such as goats, pigs and poultry.
- Solid cow dung is mixed with cow urine.

Chicken droppings make the best-quality manure because they are rich in nitrogen.

Keeping animals in partitioned enclosures allows the farmer to collect enough manure and use it in the fields.

Advantages of manure

- Using manure as fertilizer encourages the growth of beneficial microorganisms, worms and other soil organisms.
- Manure increases the organic matter in the soil, improves the soil structure and increases its water-holding capacity.
- It recycles nutrients and preserves soil fertility.
- It benefits the environment by using waste in a productive way.
- It is available on the farm.

Disadvantages and constraints

- Fresh manure is messy and can be hard to handle.
- Large amounts are needed. Collecting it and moving it from place to place is hard work. In many areas, handling manure is seen as women's or children's work.
- Fresh manure (especially urine and chicken droppings) burns crops if it comes into direct contact with them.
- Applying manure can spread weeds.

How to collect manure

Manure can be collected in different ways.

- If you allow the animals out to graze, confine them at night. You can collect the manure at regular intervals from the paddock.
- If you keep animals in a shed, shovel the manure together, along with any bedding and spoiled feed.
- Make a channel in the animal shed so urine can flow into a lined pit (see below). If you make the pit large enough, you can shovel the manure into it too.
- Spread straw or uneaten feed on the floor of the shed to soak up the urine. Collect this bedding when you clean out the shed.

Making a manure pit

1. Dig a pit to hold manure, and make the floor of the animal shed slope towards it. The pit should be large enough to hold the manure produced in 2–3 days.
2. Dig a channel leading from the animal shed to the pit, and line the pit and channel with concrete. If you cannot afford concrete, make a plaster from red soil, cow dung and ash. Smear this on the bottom and sides of the channel and pit. Repeat this five times to make them leak-proof.
3. Shovel the dung and urine into this pit.
4. Cover the pit with a plastic sheet, straw, or dry banana or enset leaves to shade it and keep out the rain. Sunlight reduces the amount of nitrogen in the manure, so reduces its value as fertilizer.

Using urine to control pests

Farmers in Woldia and northern Shoa use fermented cattle urine to control pests. They collect the urine in jerrycans and allow it to ferment for 5–15 days. They spray it using a knapsack sprayer to control pests such as *degeza* (a type of bush cricket). The urine also improves soil fertility and is biodegradable.

If you cannot make a manure pit, pile the manure in a shady place. Protect it from the rain if possible.

How to apply manure

Fresh manure (and especially fresh urine) will 'burn' plants if it touches them. To avoid this, manure has to decompose for some months. Cover it to protect it from the sun and rain before using it. You can use fresh urine directly if you dilute it in 2–5 times the amount of water.

The best time to apply manure is at the beginning of the wet season, before the crops have been planted.

Here are some ways to apply manure:

- Apply the manure directly to the soil. Work it into the soil so the nutrients in the manure are not lost to the air. Manure is usually applied before sowing annual food crops. For perennial crops, it can be applied while the crops are growing. Well-decomposed manure can be broadcast into a stand of forage.
- Make a slurry of manure mixed with twice the amount of water. Dig a furrow at some distance away from the row of plants, and pour the slurry into it. Cover the slurry to prevent the nitrogen in it from escaping.
- Use the manure as an ingredient of compost (see *Compost*, page 90).
- Make liquid manure (see below) and apply it to high-value vegetables.
- Collect urine in a pit, treat it by adding wood ash, and then apply the liquid to the soil around crops.

Manure can also be applied directly by animals.

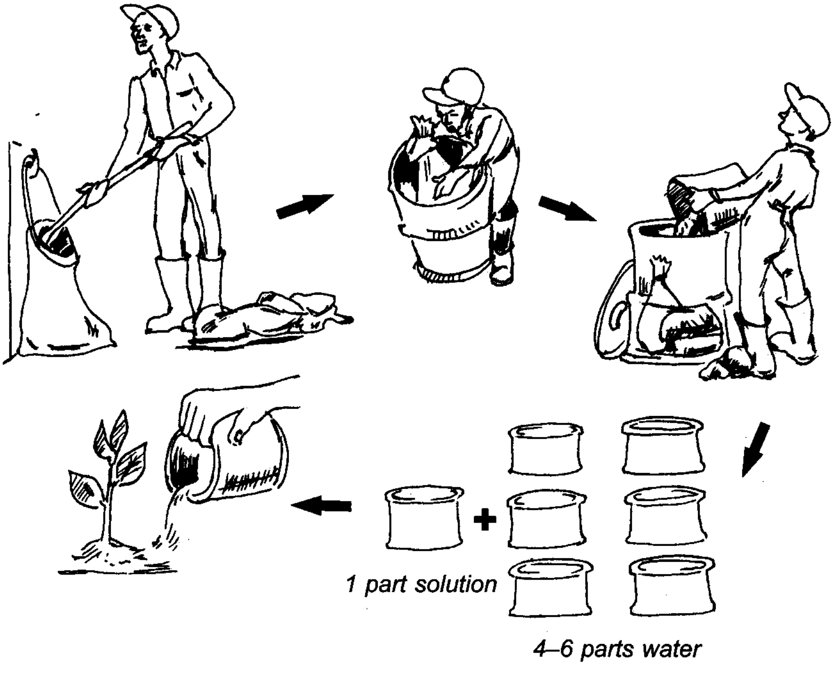
- Allow animals to graze on stubble. Their manure will stay on the soil and benefit the next season's crop.
- Keep animals in a paddock for several months. Then move them to a new paddock. Plough the old paddock and plant crops on it.

How to make liquid manure

You can make a liquid fertilizer by putting a sackload of fresh animal manure in a drum of water and allowing it to ferment. You can use the liquid manure to water high-value plants such as vegetables. Instead of animal manure, you can use nettles or fresh leaves of nitrogen-fixing trees such as leucaena and gliricidia. You can also use green grass clippings or fresh weeds.

1 Fill a sack ¾ full of wet manure, fresh leaves or compost.
2 Tie the open end, then place the bag into an empty 55-gallon drum.
3 Put a big stone on the bag to hold it down.
4 Fill the drum with water and cover it.
5 After 3 weeks, remove the bag from the drum.
6 Dilute the liquid at a ratio of 1 part of liquid to 4–6 parts of fresh water.
7 Two to three weeks after vegetable seeds germinate, use a watering can to pour the diluted liquid around the base of the plants. Avoid splashing the plants themselves. Repeat after 3–4 weeks.
8 Start over again with fresh materials following steps 1–6.

If you do not have a big drum, you can also make smaller quantities of liquid fertilizer in smaller containers or in a pit lined with clay.



How to make liquid manure

Collecting donkey dung

Donkeys working in the seed-grain market in Addis Ababa would not just bring sackloads of seed with them. They also brought – and left behind – large amounts of dung.

A local youth group, inspired by 'Gash Aberra Molla', a project to beautify the capital, made bags to hang under the donkeys' tails. They used the dung collected in the bags to fertilize gardens in the area.

This simple action had a double benefit: it solved the pollution problem in the market, and it helped beautify local gardens.

Inorganic fertilizer

Good land management means conserving water, controlling erosion, and using the available organic materials wisely to maintain and increase soil fertility. If farmers have done this, inorganic (chemical) fertilizers can help further enhance soil fertility and produce good yields – especially of high-value crops.

Inorganic fertilizers are not a substitute for organic fertilizers such as compost and manure. It is best to use them in combination. Inorganic fertilizers can be used in all agroclimatic zones.

Using inorganic fertilizers can be very profitable. A return of 30–100 birr for every 10 birr invested (US$3.60–12.00 for a $1.20 investment) is not unusual.

Advantages of inorganic fertilizer

- Inorganic fertilizer has concentrated nutrients and is easy to carry and apply. A 50 kg sack of urea contains as much nitrogen as a tonne of compost.
- Women often have to handle large amounts of manure. This is hard work. Applying inorganic fertilizer is easier and quicker.
- If applied correctly and combined with other soil- and moisture-conservation measures, inorganic fertilizers can greatly improve crop yields.

Disadvantages and constraints

- Farmers may not have the money to buy inorganic fertilizers.
- Fertilizers are not always available at the right time and in the required amounts.
- Unlike organic fertilizers, and they do not add organic matter to the soil.
- They require more skill to use than organic fertilizers. Farmers must calculate how much to apply, and when, how and where to apply it.
- Inorganic fertilizers can be a waste of money if the land is not otherwise managed well – for example, if erosion is not controlled.
- They can cause environmental pollution if they are not managed appropriately.
- Farmers have to apply fertilizers year after year to maintain high yields.

Types of inorganic fertilizer

Inorganic fertilizers may contain three main nutrients: nitrogen (N), phosphorus (P) and potassium (K). Certain types may contain other elements. All of these nutrients are present in the soil, but in different amounts. If there is not enough of one type, crops will not grow well. Farmers can make up the deficient nutrient by applying fertilizer.

How to tell maize is short of nutrients

Symptoms		Cause
• Maize leaves are pale green or yellowish • Plant is stunted and leaves are small • Tips of leaves are yellow • Ears are small and kernels are not filled	▷	Not enough nitrogen
• Leaves are purplish • Roots are few and short • Ears are short and twisted, with underdeveloped kernels	▷	Not enough phosphorus
• Browning or bronzing and scorching of leaf edges • Plant is stunted, with short distance between nodes on stem • Tips of ears are poorly filled	▷	Not enough potassium

Symptoms of nitrogen deficiency, can be cured by applying urea immediately. Overcoming phosphorus and potassium deficiency must wait for the following cropping season.

Different types of fertilizer contain different amounts of nitrogen, phosphorus and potassium. Two types of inorganic fertilizer are commonly used in Ethiopia:

- Diammonium phosphate (DAP) 18-46-0. This contains 18% nitrogen, 46% phosphorus, and no potassium.
- Urea 46-0-0. This contains only nitrogen.

A third type of fertilizer is triple superphosphate (TSP) 0-45-0. It is used on research stations. It contains only phosphorus.

Different crops need different types and amounts of inorganic fertilizer. The best type of fertilizer for tea is not necessarily the best for coffee, maize or tef. It is often best to give a balanced mix of compost, manure and inorganic phosphate fertilizer.

Sources of nitrogen, phosphorus and potassium

Nitrogen (N)

Nitrogen does not stay long in the soil – it disappears quickly. Farmers can add nitrogen to the soil by:

- Adding compost (page 90), animal manure (page 96), or green manure (especially made from leguminous plants, page 88).

- Planting pulses and other legumes – in crop rotation (page 86) or intercropping (page 82). The legumes fix nitrogen from the air and store it in the soil for plants to use.
- Adding inorganic nitrogen fertilizer, such as urea.

Phosphorus (P)

Unlike nitrogen, phosphorus stays in the soil for a long time. All crops, especially legumes, need enough phosphorus to grow well because they use it to develop roots. Certain soils in Ethiopia are deficient in this nutrient.

Farmers can add phosphorus to the soil by:

- Cutting *Tithonia diversifolia* (false sunflower) from where it grows on roadsides and riverbanks, and incorporating it into the soil as green manure. It is also possible to make a 'tea' from Tithonia and using this as liquid fertilizer (see *Liquid manure* on page 98 for how to do this). Russian comfrey (*Symphytum officinale*) can be used in the same way.
- Applying phosphorus fertilizer, such as DAP or TSP.

Potassium (K)

Most soils in Ethiopia are not deficient in potassium. For the time being, applying potassium is not as important as nitrogen and phosphorus.

When and where to use inorganic fertilizer

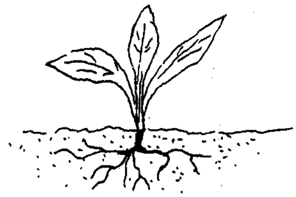
How to apply inorganic fertilizer, and how much to apply, depends on various factors:

- The soil type and its fertility.
- The amount of moisture in the soil.
- The crop type.
- The type of fertilizer.
- The cost of the fertilizer and the expected return.

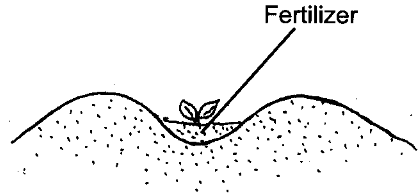
Using inorganic fertilizers does not guarantee a high yield unless they are properly managed and combined with organic fertilizers. They are best suited to areas where moisture is not a limiting factor – in areas with enough rainfall or with irrigation. If there is drought, the investment in fertilizer will be wasted.

If moisture is a problem, inorganic fertilizers should be combined with soil- and water-conservation technologies, such as terracing or water harvesting (see the sections on these). A combination of inorganic fertilizers and compost (page 90) is often a good idea.

Inorganic fertilizers often give good yields when applied to improved varieties of crops. In fact, improved varieties may need inorganic fertilizer to produce well. Inorganic fertilizers are less effective on drought-tolerant species such as sorghum and millet.



Broadcast fertilizer for crops with shallow, spreading roots.



For row crops, place fertilizer in a furrow, 7.5–10 cm deep, and mix it with soil before planting the seeds. This makes sure the crop roots can reach the fertilizer but do not get 'burned'.

Do not use inorganic fertilizers on soils that are too dry, or on waterlogged soils, as they may not have any effect.

Try to place fertilizer as close to the crop roots as possible, but not too close, as it may burn the plants or their delicate roots – especially if the soil is dry. If burning does occur, irrigation helps to reduce the damage. Nitrogen fertilizer is especially prone to burning.

Place fertilizer near each row of crops, then cover it with soil

Fertilizer jargon

Time of application

Basal dressing	Applying fertilizer before or during planting.
Top-dressing	Applying fertilizer (normally nitrogen) while the crop is growing.

Placement

Broadcasting	Applying fertilizer by throwing handfuls over the field.
Side-dressing	Applying fertilizer by putting it in a furrow to one side of a row of crops. Used mainly on maize and horticultural crops

As far as possible, try to apply fertilizer when rain showers are expected soon afterwards. The water will carry the fertilizer down into the soil to the crop roots.

Consult a crop production manual or ask the local fertilizer agent for more advice.

Fertilizing seasonal crops

Apply phosphorus and potassium either before or during planting. They can be broadcast or incorporated into the soil.

Because nitrogen dissipates easily, it does not stay in the soil for long. Farmers may have to apply inorganic nitrogen fertilizer more than once during the season at critical times during the crop's growth. For maize, for example, one dose should be given at planting time, and another after about a month, when the crop is knee-high (30 cm).

Broadcasting nitrogen fertilizer on the soil surface is wasteful, as part of it gets lost into the air. It is better to incorporate it into the soil, close to the plant roots.

During planting, nitrogen fertilizer can be applied by mixing it thoroughly with soil in the furrow. It should not come in direct contact with the seed.

While the crops are growing, nitrogen fertilizer can be applied as a side-dressing or broadcasting (see box above).

Fertilizing trees and bushes

Fertilizer can be applied to perennial crops by broadcasting it on the soil surface, or in a circle 1 m around the tree.

Storing fertilizer

Store fertilizer in a dry and shady place. Keep it away from children.

5

Conserving soil and water

Soil erosion and lack of soil moisture are major problems that Ethiopian farmers face. Many slopes are steep, and the soil is easily eroded. Farmers are forced by the shortage of land to cultivate slopes that should ideally be kept under forest or protected by a permanent cover of vegetation. Gullies can turn even gentle slopes into an unproductive wasteland.

Rainfall is often erratic, especially in drier parts of the country. It is vital to conserve moisture in the soil and make it available to the crops. Farmers must also deal with excess water during heavy storms.

Soil erosion and soil moisture are closely related. Harmful farming practices that encourage erosion also reduce the availability of moisture in the soil. Most erosion is caused by water running off the surface. If this water can be conserved in the soil, erosion can be slowed or halted.

This chapter outlines various measures to conserve soil and water. These include conservation tillage, tied ridges, grass strips, trash lines, level bunds, graded bunds, bench terraces, trenches, microbasins, cutoff drains, waterways, gully rehabilitation and checkdams. This chapter also describes several techniques needed to plan these various soil and water conservation measures: how to use simple tools to mark contour lines and graded lines, and how to measure vertical intervals and slope gradients.

Conservation tillage

Conservation tillage means ploughing less – and in different ways – in order to conserve soil and water, and to save work.

Farmers plough their fields for several reasons: to create a good seedbed for crops to grow, allow water to seep into the soil, and kill weeds. But conventional ploughing has several disadvantages. Repeated tillage exposes the soil. This allows moisture to escape into the air and breaks down valuable organic matter. It buries vegetation on the surface, exposing the soil to erosion by rain, running water and wind. Ploughing is also a lot of work, and poorer farmers often do not have the oxen and equipment they need, so must rent them from their neighbours.

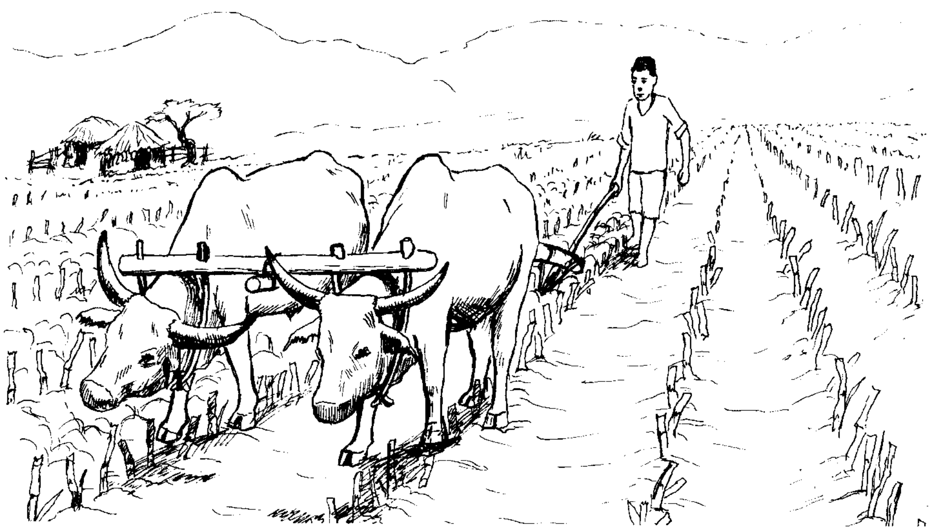
Conservation tillage avoids these problems by reducing the amount of ploughing. As far as possible, it leaves the soil and its plant cover undisturbed, so reducing the loss of water and organic matter, and protecting the soil from erosion.

Where to use conservation tillage

Agroclimatic zones Best suited to the Dega, Weyna-Dega, Kolla and Moist Bereha, but can be used in almost all agroclimatic zones.

Soils Almost all soil types. However, the particular technique will vary (see below).

Slope All types of slopes, from flat to steep. On flat land, conservation tillage is used mainly to conserve moisture in the soil. On slopes, it also helps control erosion.



With strip tillage, plough only the rows where the crop is to be planted

Types of conservation tillage

There are several types of conservation tillage:

- **Minimum or reduced tillage** Ploughing the whole field just once, instead of twice or more (as is normal in many areas). This can be used for crops that are broadcast, such as tef and wheat.
- **Strip tillage** Ploughing just the strips of soil where the crops will be planted, leaving the spaces in between undisturbed. This can be used for row crops such as maize and sorghum.
- **Zero tillage** Planting directly into the soil, usually using equipment to make planting holes or narrow furrows to put the seeds and fertilizer in. Herbicides, mulch or cover crops can be used to control weeds – but this is not practical for small-scale farmers.

The remainder of this section focuses on minimum and strip tillage.

Advantages of conservation tillage

- Conservation tillage reduces runoff and conserves water in the soil.
- It reduces erosion, improves the soil structure and conserves organic matter in the soil.
- It saves work during cultivation – though extra work is needed for weeding.
- It is less work than creating bunds or terraces (see pages 118–130), and it does not take land out of production.
- It requires some extra equipment but no other investment.
- Terracing can create alternating strips of fertile and infertile soil, because soil accumulates in the lower part of each terrace. Conservation tillage avoids this problem.

Disadvantages and constraints

- Conservation tillage allows more weeds to grow, so more labour may be needed for weeding.
- It is possible to use herbicides to control weeds, but these are expensive and hard to find, and some products may cause environmental and health problems.

Soil types

Some soils are prone to compaction (farmers know which ones they are). Not ploughing them will mean water cannot seep into the soil, and roots will not be able to grow properly. It is necessary to break up these soils by making furrows and subsoiling. This increases the amount of water that seeps into the soil, and improves aeration and root growth.

Some types of soils have a hard layer below the surface, caused by repeated digging or ploughing to the same depth. This 'ploughpan' limits the amount of water that can seep into the soil, and restricts the growth of crop roots. For conservation tillage, it may be necessary to use a special implement called a 'subsoiler' to break up these hard layers. This may have to be done every few years.

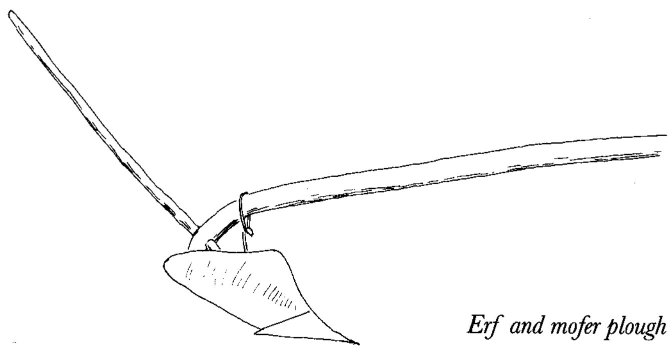
Certain heavy clay soils swell when they get wet and shrink when they dry. They do not have ploughpans, but they are prone to waterlogging, particularly in high rainfall areas. In such cases, conservation tillage can be used, but it must be combined with drainage furrows to take away the excess water.

Equipment

Poorer farmers find it difficult to plough as frequently as they wish. This means they get lower yields than their richer neighbours. These farmers can raise their crop yields by applying conservation tillage. The traditional *maresha* plough is not effective for this. They should use the following improved implements.

Plough

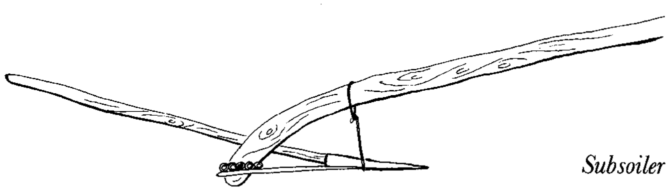
An '*erf* and *mofer* (handle and beam) attached mouldboard plough' is a special plough used in reduced tillage. Using this equipment, it is necessary to plough only once rather than several times.



Erf and mofer plough

Subsoiler

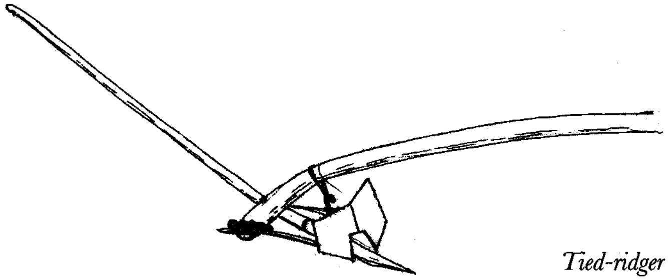
A chisel plough that penetrates deeper into the soil than a normal plough and breaks up the plough pan. It can be pulled by a pair of oxen.



Subsoiler

Tie-ridger

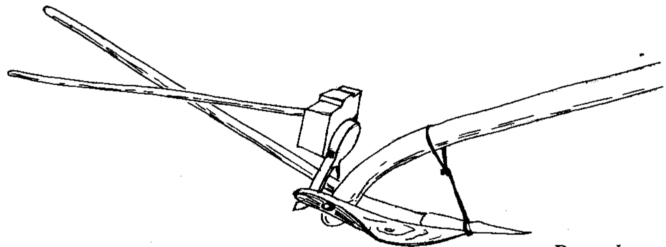
An attachment to a traditional *maresha* plough frame that creates short ridges that block the furrows and prevent water from flowing along them (see *Tied ridges*, page 111).



Tied-ridger

Row planter

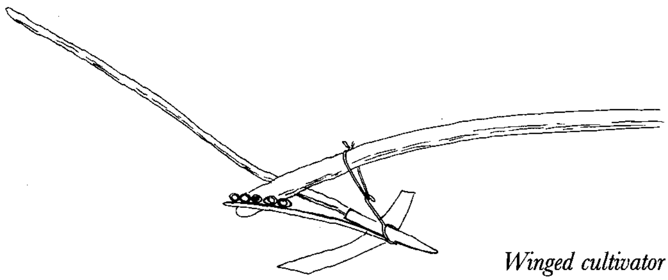
Opens furrows and places seeds and fertilizer at the bottom. It is pulled by a pair of oxen. It can be used to plant maize, sorghum or beans in single rows. A different model, not shown here, can sow wheat and legumes in two rows.



Row planter

Winged cultivator

An attachment to a traditional plough frame that cuts and uproots newly emerging weeds.



Winged cultivator

The Ethiopian Agricultural Research Organization (EARO) has developed improved versions of these implements. Manufacturers include the Akaki Spare Parts and Hand Tools Factory, and the Fana Trading Company.

How to do conservation tillage

The most appropriate conservation-tillage method depends on the amount of rainfall, the soil type and crop. If there is a ploughpan, use a subsoiler to break it up before applying conservation tillage.

Strip tillage for crops planted in widely spaced rows

This is used for maize, sorghum, cotton, groundnut and other crops.

1 Make furrows using a *maresha* plough at a spacing of 75 cm.
2 Use the subsoiler along these furrows.
3 Sow the seeds and fertilizer using a row planter.

4 While the crop is growing, use a winged cultivator between the rows to control weeds.

Strip tillage for crops planted in narrowly spaced rows

This is used for wheat, barley and beans.

1 Make furrows using a *maresha* plough at a spacing of 50 cm.
2 Use a row planter to sow the seeds and fertilizer.
3 While the crop is growing, use a winged cultivator between the rows to control weeds.

Reduced tillage for broadcast crops

This is used for tef, wheat, barley and beans.

1 Make furrows at 75 cm spacing.
2 Use the subsoiler along the furrows. On soils that are prone to compaction, it may be necessary to subsoil the land again if rainy spells and dry spells alternate, to prevent the soil from hardening.
3 One month before planting, use the *erf* and *mofer* attached mouldboard plough to plough the whole field. It is normally necessary to plough only once.
4 If you want to plant tef, make shallow furrows 2–3 m apart using a *maresha* plough to mark the areas for broadcasting the seed and fertilizer. Broadcast the fertilizer and use the winged cultivator to kill newly emerged weeds and to incorporate the fertilizer. (If the field is full of trash, use the winged cultivator first, then apply fertilizer. This avoids bulldozing the fertilizer with trash.) Use a tied-ridger along the shallow furrows to prevent water from running along them. Then broadcast the tef seeds.
5 If you want to plant wheat, barley or beans, broadcast the seeds along with the fertilizer, and then use the winged cultivator to bury the seeds and to control weeds.

Success with tef

Farmers in the Wulinchity area, East Shoa, in the Dry Weyna-Dega, were trained how to use improved implements and conservation tillage without herbicides. Sisay Tekle Sellasse was one of the farmers who decided to try out the technology. He planted tef in 2001, using the method described above.

Sisay's trial was successful. He reduced the number of ploughings, controlled weeds in his fields better, and got a higher tef yield than in previous years. He says that his field looked a lot better than those of his neighbours who had not used conservation tillage.

Tied ridges

Tied ridges are a series of cross-ridges that interrupt furrows and stop water from flowing along the furrow. The water is trapped between the ridges and seeps into the soil.

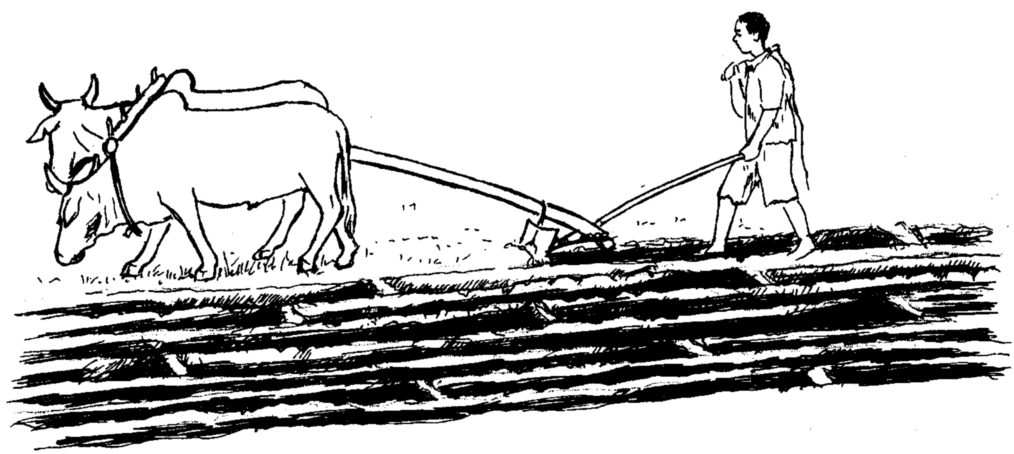
Where and when to use tied ridges

Tied ridges are ideal in areas with limited moisture.

Agroclimatic zones Dry Dega, Weyna-Dega, Kolla and Bereha.
Soils All soil types, but they may cause waterlogging in poorly drained soils.
Slopes Useful on all slopes.

Choose when to make the tied ridges carefully.

- If no rain is expected after planting (e.g., if maize or sorghum is planted in April/May), tied ridges will make the soil dry out more quickly as they allow more moisture to evaporate. Avoid tied ridges at this time, and use closed furrows to minimize the surface area of soil exposed.
- If rain is expected after planting (e.g., when planting is in June), make tied ridges during planting or at a later stage, such as in mid-July or afterwards. If the plants turn yellow due to waterlogging, break the tied ridges and carefully drain the excess water away.



Making tied ridges

Advantages of tied ridges

- Tied ridges conserve moisture in drought-prone areas, increasing crop yields.
- They prevent water from flowing along the furrows, so help avoid erosion
- A tie-ridger is affordable and can easily be attached to the traditional *maresha* plough. It is simple to use and maintain.

Disadvantages and constraints

- Tied ridges may cause waterlogging in poorly drained soils and in case of heavy rains.

How to make tied ridges

You will need a pair of oxen and a traditional *maresha* plough with a tie-ridger attachment (see page 109).

1 Attach the tie-ridger to the plough.
2 While ploughing, lift and drop the tie-ridger at regular 5–10 m intervals in order to create ridges as the plough is pulled forward. Use a short spacing of 5 m on steep slopes where the rainfall intensity is high, and where the soils do not hold moisture for long. On gentle slopes, use a row spacing of 1.5 m and a tying interval of about 10 m.
3 With row planted crops, place seeds and fertilizer at the bottom of the furrow where the rainwater accumulates.

Combinations

Tied ridges can be combined with contour ploughing to prevent soil erosion (see page 148 for how to mark contours).

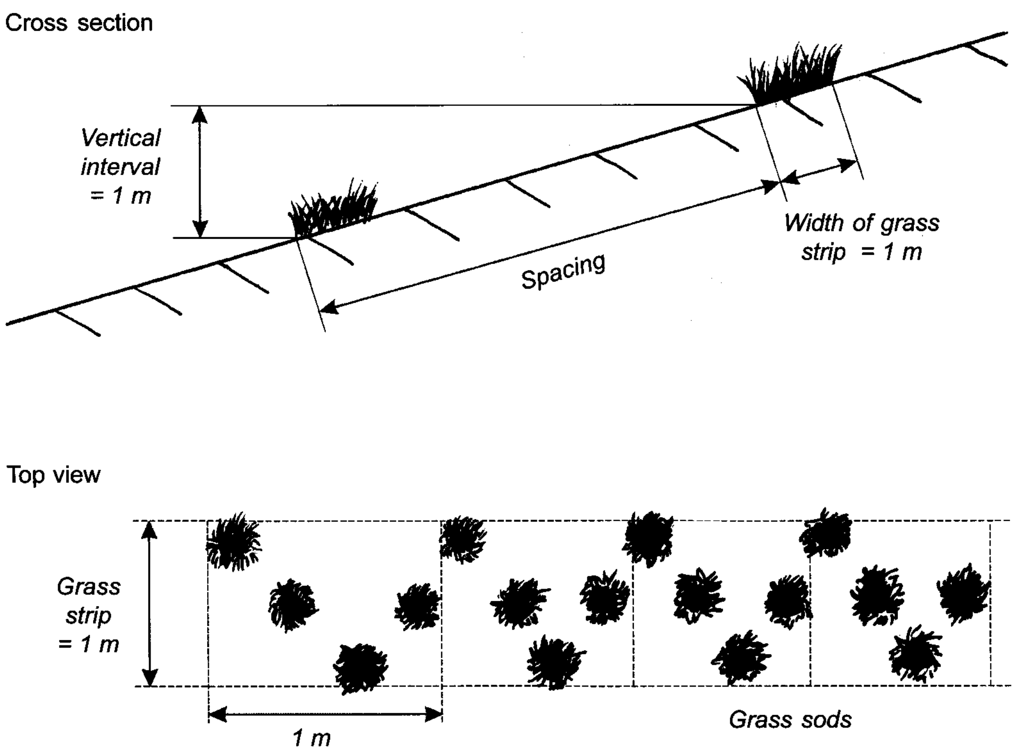
Grass strips

A grass strip is planted along the contour on cultivated land to reduce the amount of water flowing down the slope and to retain soil. Usually, grass strips are about 1 m wide. They are used mainly to replace physical structures (such as bunds, see page 118) on gentle slopes.

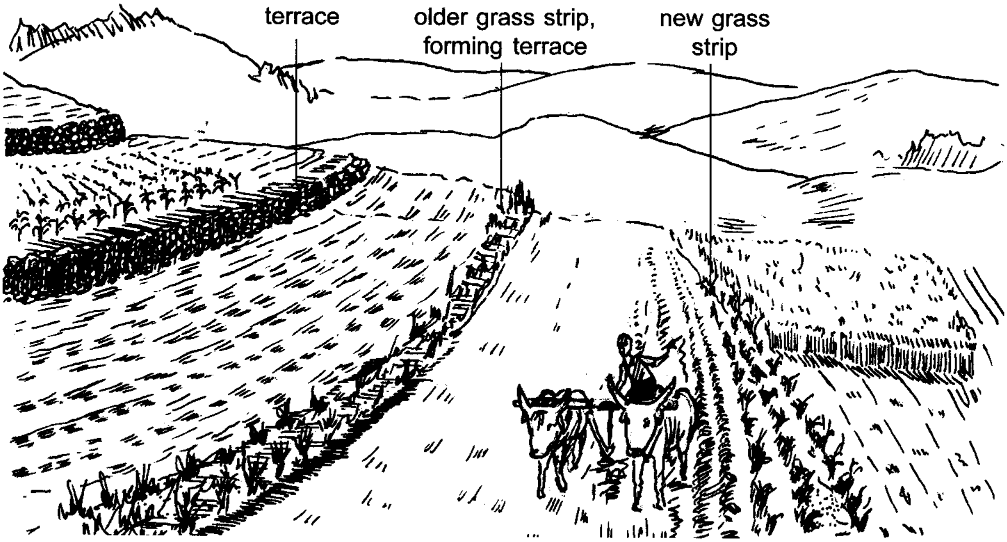
Grass strips are suitable where the climate is not too dry for grass to grow densely. If no grazing is allowed the grass strips build up into terraces and provide fodder for livestock.

Where to use grass strips

Agroclimatic zones All moist and wet areas.
Slopes Less than 15% gradient.
Soils All, especially sandy and silty soils where water seeps into the ground easily.



Cross-section and top view of grass strips



Grass strips are used on the gentle slope to the right. Terraces help conserve soil on the steeper slope to the left. The strips and terraces guide the farmer to plough along the contours, further reducing erosion. The individual sods of grass planted into the strip can still be seen. In the centre of the picture, the grass strip has already developed into a small terrace.

Advantages of grass strips

- Grass strips help reduce runoff and trap eroded soil.
- If they are not grazed, the grass strips will build up into terraces.
- The strips provide cut-and-carry fodder for cattle.

Disadvantages and constraints

- Grass strips are not effective in arid areas.
- When they are newly established, the strips do not offer much protection against erosion.
- The strips can easily be overgrazed and damaged by animals.

How to make and manage grass strips

1 Mark out contour lines (see page 148) at vertical intervals of 1–2 m (or see the table on the next page for the spacing at different gradients).
2 You can sow grass seed, or plant sods from a well-developed grassland nearby. Select a palatable grass species (farmers can tell you which type they prefer). Grass that forms runners is not suitable because it will disturb the crops.

Spacing for grass strips down a slope

Slope (%)	Spacing (m)
<3	>33
3–5	20–33
6–8	13–18
9–11	10–12
12–15	7–9

3 When the grass has grown, encourage farmers to cut-and-carry grass rather than allowing animals to graze the strips. The grass should be resown or replanted if necessary. Make sure the strips do not get narrowed by ploughing: they have to be at least 1 m wide to be effective.

Strips can also be planted along a cutoff drain (page 137).

Trash lines

Trash lines are made from crop residues, grass and other organic materials collected from the field. These are arranged along the contours at appropriate intervals. They slow down surface runoff and reduce soil erosion. Trash lines are used to replace physical structures like stone or soil bunds on gentle slopes. They are usually about 1 m wide.

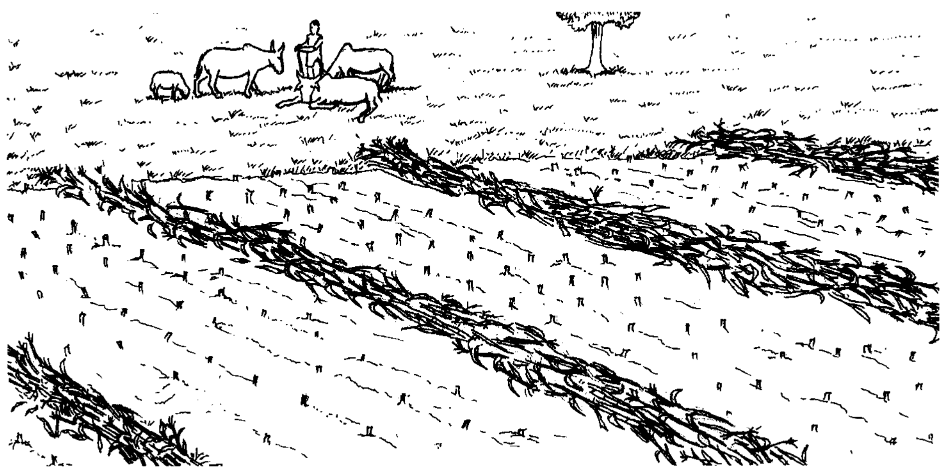
Where to use trash lines

Trash lines are useful in areas where crop residue and other trash found in the field is not used for livestock feed or for fuel.

Agroclimatic zones All Dega and Weyna-Dega, Moist and Wet Kolla, and Moist Bereha.
Soils All soil types.
Slopes Gentle slopes less than 15%.

Advantages of trash lines

- Trash lines slow down surface runoff that could cause soil erosion.
- They retain soil, gradually building up terraces along the contour.
- They also allow rainwater to seep into the soil, raising its moisture content.
- The trash eventually decomposes, adding organic matter to the soil, helping retain moisture and improving the soil fertility.



Trash line on a gentle slope

Disadvantages and constraints

- Trash lines are not practical in dry lowland areas and other agroclimatic zones where trash is in short supply.
- They tend to harbour diseases, insect and rats. If this is a problem, consider ploughing the trash into the soil, or using other soil-conservation techniques.

How to make trash lines

- Mark out the position of the trash line using a line level or an A-frame (see page 148). The spacing between the lines depends on the slope. On gentle slopes, the spacing can be more than 5 m.
- Collect the trash from the field and arrange it along the contour lines you have marked out.
- You can knock pegs into the ground to keep the trash line in place.

Level bunds

A level bund is an embankment or ridge built across a slope along the contour. It prevents water from flowing down the slope, and so also prevents soil erosion. The embankment is about 50–75 cm high on the upslope side. Water is trapped behind this wall and percolates into the soil.

Soil accumulates behind the bund, and over time creates a level bench-like terrace. This retains fertility and moisture, leading to higher yields of crops grown on the land between the bunds.

The bund may be a simple ridge of soil, a line of large stones with the gaps filled in with earth, a ridge of soil faced with stones on the downslope side, or a wall built entirely of stones. The bunds can be planted with grasses, fodder legumes and trees.

The bund may have a shallow ditch running along its upper side. Tied ridges (page 111) interrupt this ditch about every 10 m. They stop water from flowing along the ditch. That means large pools of water do not form in one place and flow over the top of the bund at its lowest point.

The ends of the bund are usually closed with a short ridge to prevent water from flowing around them and creating a gully.

Where to use level bunds

Agroclimatic zones All moist and dry zones, except Moist Bereha and Moist Alpine Wurch. Use cutoff drains in addition if the rainfall is high (see page 137).

Soils Level bunds are ideal on soils deeper than 50 cm. They can also be used on shallower soils, for example to rehabilitate degraded land. Pay particular attention to farmers' experiences of erosion on these soils.

Slopes 3–50% (20% is the maximum slope if farmers plough with oxen).

Advantages of level bunds

- Bunds hold water and allow it to soak into the ground. They prevent water from draining away and causing gullies.
- Soil gradually builds up behind the bunds, producing a bench terrace.
- Soil fertility also builds up on the terrace, producing higher yields.
- Bunds can be built by an individual farmer or by a group.
- The bunds can be used to produce feed for animals.

Disadvantages and constraints

- Building bunds needs a lot of labour. (Organize a group of farmers to build them quickly.)
- The bunds take land out of crop production. (Planting grasses, fodder crops or fruit trees makes them productive.)
- Breaks in a bund can cause gullying. (Make sure the bunds are close enough together to prevent large amounts of water from building up in heavy rains. Repair breaks promptly.)
- Rats may live in the bunds, especially those made of stone. (They can be controlled using conventional methods or by using thorny branches – see page 123.)

How big to make bunds

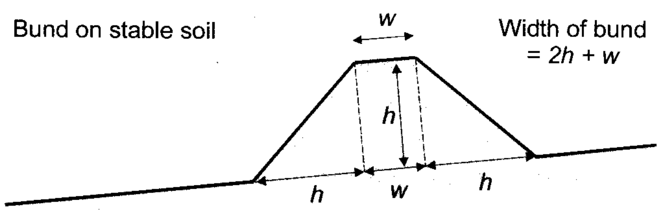
Bunds must be large enough to withstand trampling by livestock or people. Weak bunds break easily if they are damaged.

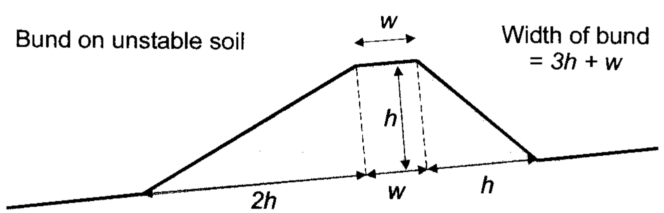
When first built, bunds should be about 0.65 m high (about knee-high) on the upslope side. This is high enough to allow for the soil in the bund to settle a little, and to trap a pool of water 50 cm deep behind them.

The width of the bund depends on the soil type. If the soil is stable (for example, a loam), make the base about 1.6 m wide, and the top about 0.3 m wide. If the soil is unstable (for example, if it is sandy), make the base wider (about 2.25 m).

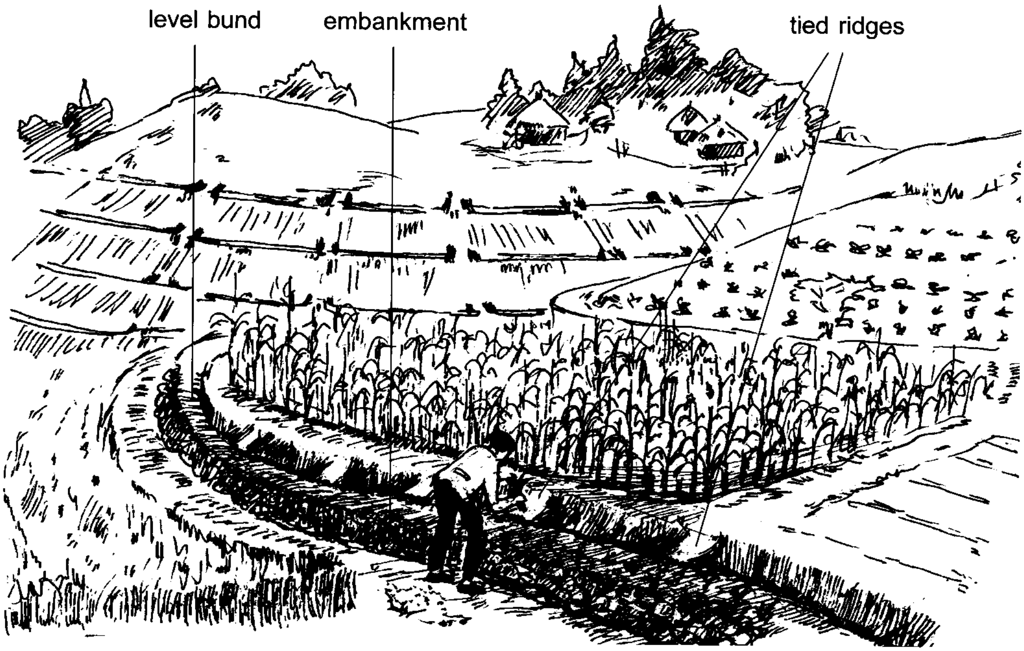
Bunds can be built higher than 0.65 m, but this depends on how stable the soil is.

- For stable soils, make the base twice the height of the bund, plus the width of the top.
- For less stable soils, make the base three times the height, plus the width of the top.





Cross-sections showing bund dimensions on stable and unstable soils. If the soil is unstable, the bunds have to be wider than on stable soils.



The level bund in the front of the slope follows a horizontal line. The ditch behind the bund is interrupted by tied ridges about every 10 m. The newly constructed embankment still needs to be planted with grasses.

Bunds over 1 m high should usually be made of stone. Stone bunds can have more vertical walls, reducing the amount of land needed. Stone bunds may also need a foundation.

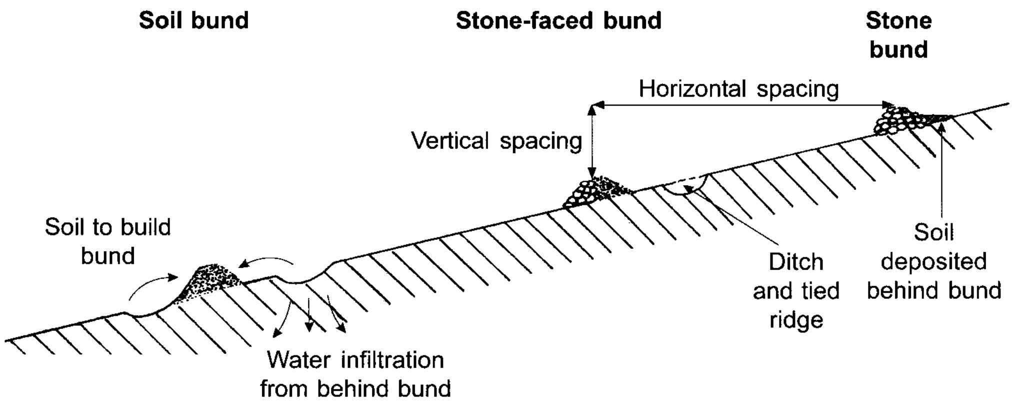
How far apart to space bunds

The spacing between bunds depends on several factors. Considerations include:

- Steeper slopes need more bunds so they can develop into bench terraces.
- The terraces between the bunds should be wide enough for farming. Farmers who plough with oxen often do not like terraces less than 7 m wide. Farmers who cultivate using hoes may accept smaller distances between bunds.
- Bunds take land out of crop production. For example, a bund 1 m wide every 10 m reduces the area available for crops by 10%. This means that yields must be at least 10% higher on the remaining land for the farmers to want to build the bunds.

Spacing of bunds

Slope	Spacing between bunds
Less than 5%	15 m or more
6–10%	10–14 m
11–15%	8–9 m
16–20%	7 m
More than 20%	Less that 7 m. Use bench terraces if possible.



Types of bunds

Farmers will be reluctant to build or maintain bunds if they do not see major benefits from them.

It is usually better not to dig a ditch behind the bund because only the nearby crop plants benefit from the water trapped there. If there is no ditch, the water can spread over a wider area, and more plants benefit.

If necessary, leave gaps in the bund to allow people, cattle and equipment to move from one terrace to the next. Close off the ends of the bunds on either side to prevent water from overflowing and creating a gully.

How to make a level bund from soil

You will need an A-frame or line level, digging tools, and stones for stone bunds. To stabilize the bund, you will need suitable grasses, legumes and tree seedlings.

Here is how to make a bund from soil.

1 Work out the gradient of the slope (see page 157).
2 Decide on the spacing of the bunds (see the table on the previous page for guidance). Use sticks to mark out where to begin building each bund down the slope.
3 At the top of the slope, mark out a contour line (a line running at the same height across the slope) where you want to build the first bund (see page 148).
4 Scrape the soil from either side of the contour line, remove the grass so the soil can be compacted, and pile soil and stones up to form an embankment running along the line.
5 Compact the embankment and shape it so the top is level.
6 Move down the slope to where you want to build the next bund and repeat steps 3–5.
7 Plant the bunds with grasses, fodder legumes and trees to stabilize them and make them productive.

Seven reasons farmers destroy conservation structures

Bunds are popular in many areas. But farmers sometimes fail to maintain, or even deliberately destroy, the conservation structures (level bunds, terraces, etc.) that they themselves have built. Here are some reasons they do this:

1. The wrong plants have been chosen to stabilize the structures. These plants invade the nearby fields and become weeds. Plants that produce runners often do this.
2. Bunds and terrace risers harbour rats.
3. Farmers hope to be paid (food for work) to rebuild the structures.
4. Farmers do not see immediate benefits from the structures.
5. Development agents fail to communicate the long-term benefits of the structures.
6. The structures take land out of production.
7. Poorly designed or poorly built structures on steep slopes collapse.

Development agents should be aware of these problems and discuss the benefits of conservation structures with farmers beforehand (see Chapter 2). There are ways to overcome the problems.

How to make a stone bund

Stone bunds need a foundation to make them stable.

1. Measure the slope and mark out the contour (see steps 1–3 above).
2. Dig a shallow trench 0.3 m deep and 0.2–0.3 m wide along the contour. Place large stones in the trench, then pile other stones on top of them to build a wall.
3. Use smaller stones and soil to fill any gaps and to reinforce the back of the wall.
4. Continue to build the wall with stones until you reach the desired height. Fill in behind it with soil.
5. Plant the bund with grasses, fodder legumes and trees.

Bunds can be built entirely of stone. Just pile large stones along the contour, and fill in any gaps between them with smaller stones, soil and thorny shrubs.

Stabilizing bunds using trees

The slopes are steep in Tikurso catchment, Tarma-ber *woreda* (Moist Weyna-Dega agroclimatic zone), so double stone risers are needed to make sure the bunds are stable. But the risers are wide and take up a lot of land.

Ato Gebriye, a local farmer, has put his risers to good use. On the upper side of the riser, he plants a line of *Rhamnus prinoides* (*gesho*), a tree used in brewing beer. He bends the upper branches down and buries part of the branch. The branches produce roots, and eventually a new tree begins to grow. This technique is called 'layering'.

Ato Gebriye also plants calabash on the terrace sides and trains the runners to grow up to the top of the terrace.

Other farmers in the area grow *Ehretia cymosa* (*gamein*), *Grevillea robusta* and *Croton* at 1 m spacing along the base of the riser to support it.

Using vetiver to stabilize bunds

Farmers in Illubabor (Wet Weyna-Dega agroclimatic zone) at first refused to build level bunds because they were afraid the bunds would require a lot of maintenance. The NGO Menschen für Menschen started some demonstrations on a few farms and in schools. The demonstrations showed how to use vetiver grass (*Vetiver zizanoides*) to stabilize soil conservation structures. The NGO invited the local farmers to see the demonstrations for themselves.

The farmers were impressed. They started planting existing bunds with vetiver. They also saved labour by planting vetiver in a shallow furrow along the contour, rather than building a soil bund.

They thought it was so good that between 1993 and 2000, they established 2190 km of vetiver hedge. They are not interested in building more structures unless they can get vetiver planting materials.

How to maintain level bunds

- Check the bunds after every heavy rain and in each season. Repair breaks promptly to avoid gullying.
- Raise the height of the bunds as soil builds up behind them. The bund should always be at least 50 cm above the ground behind it. Over time, this will build up a horizontal bench terrace.

Combinations and alternatives

In moist areas, or in areas where the rainfall is likely to be heavy, dig a cutoff drain first, upslope from the topmost bund. This diverts heavy runoff away from the bunds and terraces, so avoids overtopping and waterlogging (see page 137).

In moist areas or areas with intense rainfall, level bunds can lead to waterlogging and overflows. Graded bunds (page 124) are better in such areas.

Level bunds can be used on degraded land and shallow soils, but bench terraces develop very slowly. In such areas, consider using microbasins or trenches, or closing the area to livestock for 5–10 years, then using level bunds.

Controlling rats

Farmers in the Tikurso catchment, Tarma-ber *woreda* (Moist Weyna-Dega agroclimatic zone) came up with an innovative way to keep rats from infesting their stone terraces.

When building a terrace, they first excavated a shallow trench 5–10 cm deep along the contour line. They filled this with thorny branches such as *Carissa edulis* (*agam* in Amharic), *Rhus natalensis* (*chakma*) and *Rhus vulgaris* (*kimo*). They then piled stones on top of the branches, and filled in any gaps with more thorny plants.

The terraces are stable, even on steep slopes – and free of rats. The farmers have built them without any payment.

Graded bunds

A graded bund is an embankment or ridge made of soil or stones built across a slope. Unlike a level bund (which runs along a contour line), it slopes gently at a gradient of between 0.4% and 1% towards a waterway or river. This allows excess water to drain away. The gradient must be very gentle; if it is too steep, the channel behind the bund could be scoured, causing a gully. But if the gradient is not steep enough, soil will build up in the channel and eventually cause an overflow.

Where to use

Agroclimatic zones All moist and wet zones.
Soils All soils in wet agroclimatic zones, and clay soil in moist zones.
Slopes 3–50%.

Advantages of graded bunds

- Bunds reduce the speed of water running down the slope. This prevents erosion and the formation of gullies.
- Most of the soil eroded between two bunds is deposited behind the bund, eventually forming a bench terrace.

Disadvantages and constraints

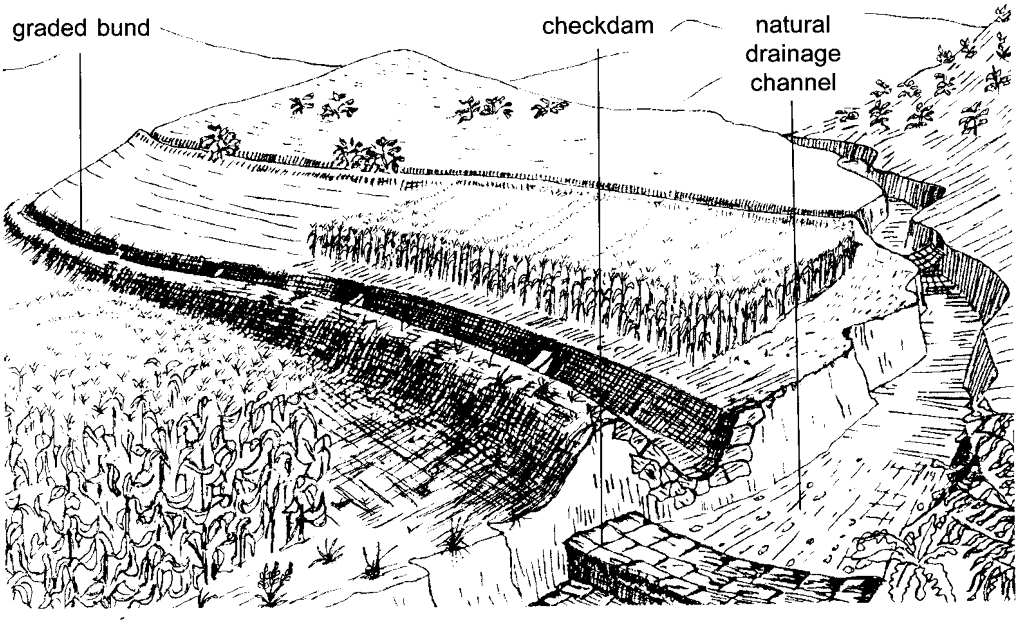
These are similar to level bunds (see page 118).

How big to make a graded bund

The ditch behind the graded bund must be made larger at its lower end, close to the waterway, because there is more water there than at the upper end of the bund. The ditch can be 25 cm deep and 50 cm wide at the upper end of the bund, and 50 cm deep and 100 cm wide about 100–150 m down the slope, close to the river or waterway.

Safe gradients for graded bunds

Soil	Safe gradient (%)
Erodible soils (silty and fine sandy soils)	0.25
Moderately erodible (loam soils)	0.5
Less erodible (clay soils)	1.0
Gravel and stones	> 1.0



The graded bund in the foreground enters a natural drainage channel. A checkdam protects the natural channel just below where the graded bund joins it.

A graded bund should be as short as possible. If the bund is longer than 200 m, it may collect too much water, which may overflow and break the bund.

How to make a graded bund

To make a graded bund you will need an A-frame or line level, digging tools and suitable grasses, legumes and tree species.

1 Measure the gradient of the slope and check the soil type. These will determine the safe gradient for the bund (see the table on the previous page) and the spacing between the bunds (see next page). You can measure the slope gradient using a line level (see page 157).
2 Go up the waterway or channel where you want the bund to drain into, to the top of the slope (see the diagram on the next page). Starting here, use the line level or A-frame to mark out where to build the bund (see page 152 for how to do this).
3 Scrape the soil from either side of the line you have marked, remove the grass so the soil can be compacted, and pile soil and stones up to form an embankment running along the line.
4 Compact the embankment and shape it so the top is level.
5 Move down the slope to where you want to build the next bund. Repeat steps 2–4.
6 Plant the bunds with grasses, fodder legumes and trees to stabilize them and make them productive.

Spacing between bunds

Slope (%)	Spacing (m)		
	Sandy soils (easily erodible)	Silt loam soils (moderately erodible)	Clay soils (less erodible)
3–8	15–40	20–50	25–60
9–20	8–14	8–19	10–24
21–40	4–7	5–7	5–10
41–50	3–4	3–4.5	4.6–5.8

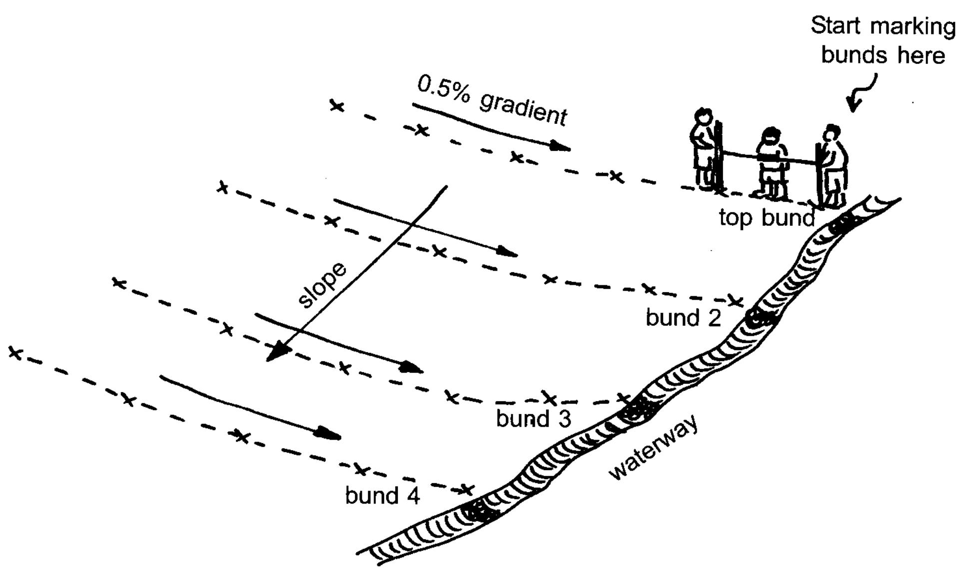
Source: Daniel, 2001

How to maintain graded bunds

- Check the bunds after storms and repair any damage promptly.
- Raise the height of the bunds each year until a bench is developed.

Combinations

- Build a cutoff drain (page 137) upslope from the top bund. This diverts excess water away from the bunds, avoiding overtopping and waterlogging.
- It is always better to allow the bunds to drain into a natural waterway. If you have to use an artificial waterway, make sure that it is properly located. Make sure that the excess runoff does not damage the fields downslope.



Marking where to build graded bunds

Bench terraces

A bench terrace is a level (or almost level) step built on a slope. The bench terrace either can be built directly, or it can develop slowly from level bunds (page 118). A series of bench terraces looks like a staircase up a slope. The flat area between the terrace risers is used for growing crops.

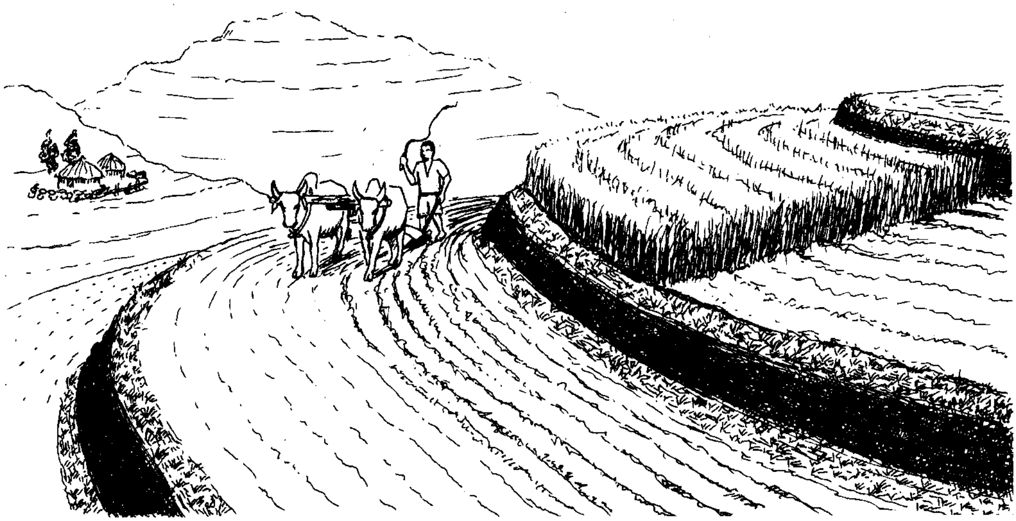
In dry to moist agroclimatic zones, bench terraces are built along the contour and are called 'level bench terraces'. In moist to wet zones, the terraces slope gently to allow excess rainwater to drain away. They are called 'graded bench terraces'.

Where to use bench terraces

Agroclimatic zones All agroclimatic zones where agriculture is practised.
Soils All soil types, but the soils must be deep (see the table on the next page).
Slopes Slopes up to 50%.

Advantages of bench terraces

- Levelling the cultivated land reduces soil erosion.
- Benches convert hillsides into level land that is suitable for planting crops.
- Grass and legumes can be planted on the terrace walls and used to feed animals.



Ploughing a bench terrace

Disadvantages and constraints

- Terraces take a lot of work to build and maintain.
- Terraces are not suitable on shallow soils because of the large amount of earth that must be moved.
- The design and construction are complicated. (Farmers needs proper training.)

Spacing

The spacing of benches depends on the slope and the depth of the soil. The vertical distance between the base of one bench terrace wall and the base of the next one down the slope should be 2.5 times the depth of the soil. For example, if the depth of the soil is 1 m, the base of one wall should be 2.5 m above the base of the next wall down the slope. See page 155 for how to measure this height difference.

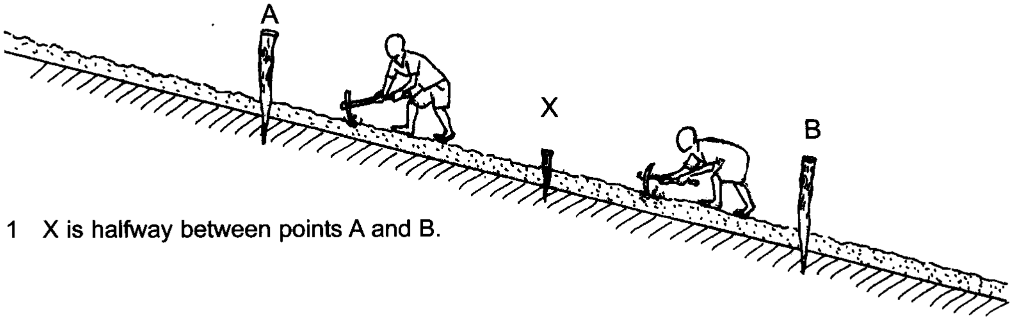
Steeper slopes and unstable soils need more terraces because they erode more easily than gentler slopes and stable soils. See the table below for guidelines.

How to build a level bench terrace

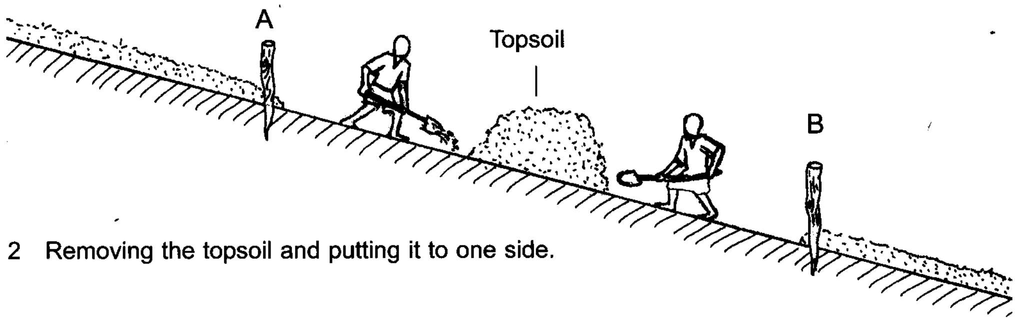
1. Measure the gradient of the slope using a line level (see page 157). Check how deep the soil is. Using the table below, decide how wide the bench should be.
2. At the top of the slope, use a stick mark where to build the first terrace wall (point A in the first diagram on the next page). Use a line level or A-frame to mark out a contour line from this point (page 148).
3. Measure the width of the bench and mark where to build the next wall (point B in the diagram). Mark out a contour line from this point. Repeat this process to mark out the location of all the walls down the slope.
4. Measure half the distance between the first and second lines (point X in diagram 1 on the next page).
5. Remove all the topsoil from the whole area to be levelled, and pile it at a convenient place to one side (diagram 2).

Width of cultivated land on bench terraces at different slope gradients and soil depths

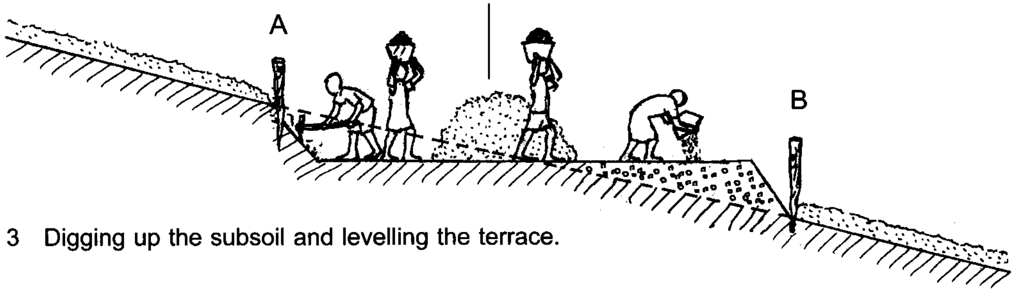
Slope (%)	Soil depth (cm)					
	25	50	75	100	125	150
20	3 m	6 m	8 m	11 m	14 m	17 m
30	2 m	4 m	5 m	7 m	9 m	11 m
40	1 m	3 m	3 m	5 m	6 m	8 m
50	1 m	2 m	3 m	4 m	5 m	7 m



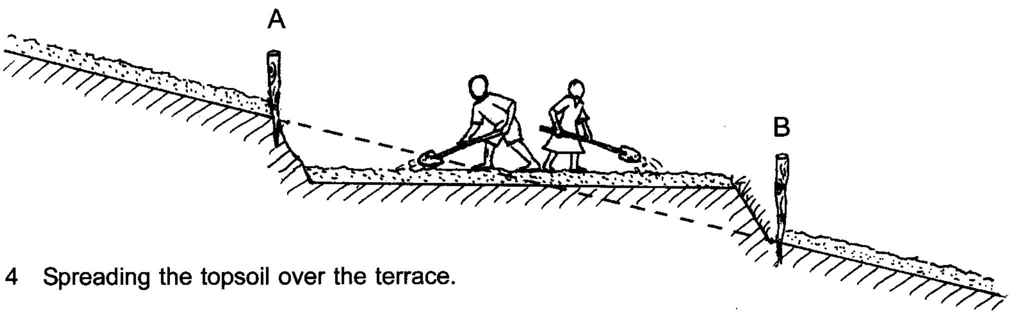
1 X is halfway between points A and B.



2 Removing the topsoil and putting it to one side.



3 Digging up the subsoil and levelling the terrace.



4 Spreading the topsoil over the terrace.

Cross-sections showing how to build a bench terrace

6 Dig up the subsoil between points A and X. Move it to between X and B, and level it (diagram 3).
7 Spread the topsoil across the terrace (diagram 4).
8 Incline the terrace walls at an angle of 45 degrees. If the area has many stones, use them to build the terrace walls (see *Level bunds*, page 118).
9 Stabilize the terrace walls with grass and other suitable plant species.

How to build a graded bench terrace

1 Dig a waterway (page 139) to carry runoff from the terraces you will build.
2 Then follow steps 1–10 above for the level bench terraces. Instead of marking out contour lines (steps 2 and 3), mark out lines that slope gently across the slope towards the waterway. See page 152 for how to do this.

How to maintain bench terraces

- Stabilize the walls with suitable grasses and other plants.
- Check the terrace walls regularly, and repair them if necessary.

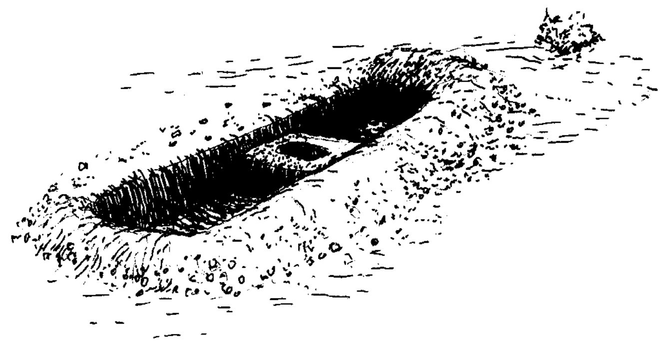
Combinations

In areas where rainfall is heavy, build a cutoff drain upslope from the top bench. This protects the bench from runoff that may damage it.

Trenches

A trench is a short ditch or pit dug across the slope to trap water. Trenches are used to help rehabilitate degraded land. They should be located where runoff usually occurs.

The trench traps water that would otherwise run down the slope, and allows it to seep into the soil. The soil removed from the trench is used to make an embankment on its lower side.



Trenches are good places to plant trees in dry areas because of the water they collect. Planting pits can be dug in the middle of the trench to plant seedlings.

The embankment may have grasses or legumes planted on it. These plants can be cut and fed to livestock.

Where to use trenches

Agroclimatic zones Moist Wurch; Moist and Dry Dega, Weyna-Dega and Kolla; Dry Bereha.

Soils All.

Slopes All.

Advantages of trenches

- Trenches help recharge the water table and maintain a supply of water for wells and springs.
- They protect the soil downslope from erosion.
- They enable trees to grow quickly. They are one of the few ways to grow trees in dry areas (see also *Microbasins*, page 133).

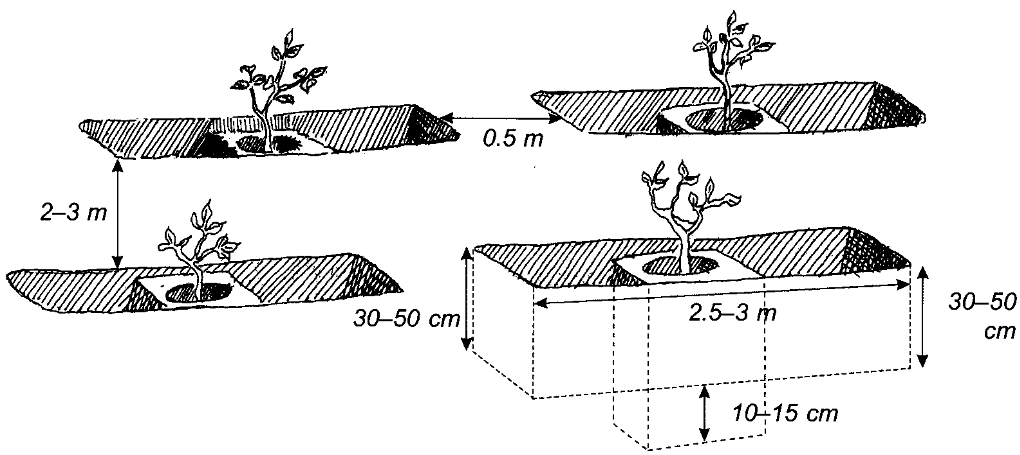
Disadvantages and constraints

- Digging trenches is hard work.

How to make a trench

A trench is normally 2.5–3 m long and 0.3–0.5 m deep, depending on how deep the soil is. Trenches should be spaced about 0.5 m apart along the contour, and about 2–3 m apart down the slope. Trenches should be staggered in alternate rows so that overflow from one row runs into the next row down the slope.

To make the trench you will need an A-frame or line level (see page 148), tools for digging and suitable tree species.



Trench layout

1 Start at the top of the slope. Decide where the trenches will be located.
2 Dig a trench 30–50 cm deep, 50 cm wide and 2.5–3 m long along the contour.
3 Use the soil dug out to make an embankment along the lower side of the trench.
4 If you want to plant a tree in the trench, leave some soil undisturbed in the middle of the trench, then dig a pit in this soil. The bottom of the pit should be 10–15 cm lower than the bottom of the trench. Plant a seedling in the pit (see *Bare-rooted seedlings*, page 240, or *Growing seedlings in pots*, page 243).

How to maintain trenches

- Repair broken embankments after storms.
- Remove silt as it builds up in the trench. Use it to build up the embankment.
- Cut the vegetation growing on the embankment and feed it to livestock.

Combinations

Trenches are often used in combination with terraces and level bunds (see pages 118–130) where there is a lot of runoff.

Microbasins

Microbasins are shallow basins surrounded by earth bunds, built within crop fields. They collect rainwater and allow it to seep in the soil, where plant roots can reach it. The basins are usually staggered in alternate rows so that overflow from one row runs into the next row down the slope.

Microbasins are usually not more than three times the size of the planting area. The size of the basin depends on the amount of water that needs to be conserved. They can be as large as 30 m^2. Use small basins in moist areas and large ones in dry areas.

There are many different types of microbasins. They include:

- Half-moon or trapezoidal basins.
- Negarim (diamond) basins.
- Contour bund microcatchments.

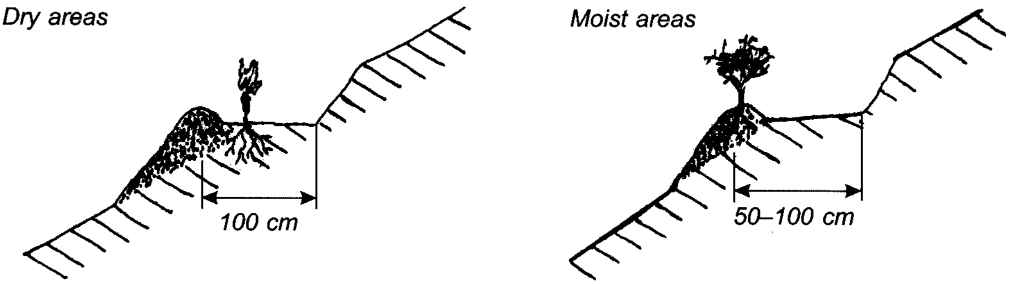
Where to use microbasins

Agroclimatic zones All dry and moist areas.

Soils All soils except very degraded land. Ideally, soils should be not too clayey (so water seeps in easily) but not too sandy (so it stays in the soil rather than percolating further down). Soils should be fairly deep, so enough water in can be stored in the soil, and so roots have enough room to grow.

Slopes All, but most appropriate on slopes less than 5%.

Microbasins are used for planting trees in dry areas. The farmer digs pits in the centre of each basin so she can plant seedlings.



Cross section of microbasins

Advantages of microbasins

- Microbasins collect water that would otherwise flow down the slope.
- In dry areas, microbasins are one of the few ways to plant trees.
- In windy areas, the microbasins also trap fertile windblown soil.

Disadvantages and constraints

- Making microbasins takes a lot of work, and cannot easily be mechanized.
- It is not possible to cultivate with tractors because this would damage the bunds.

Half-moon and trapezoidal basins

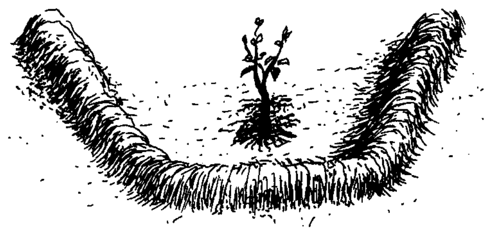
Half-moon basins are semicircular earth bunds, aligned along the contour. Water collects inside the half-moons. Water that overflows is caught in the next half-moon downslope.

Commonly, the half-moon basins have a diameter of 2–2.5 m. They are spaced 0.5–1 m apart across the slope, and 3–6 m apart down the slope. The best size and spacing depends on the local climate: in dry areas, they can be very much larger (up to 30 m in diameter).

Trapezoidal basins are similar, only the bunds are straight rather than curved.

The basins are used to rehabilitate denuded rangeland or to produce fodder. They can also be used from growing trees or crops.

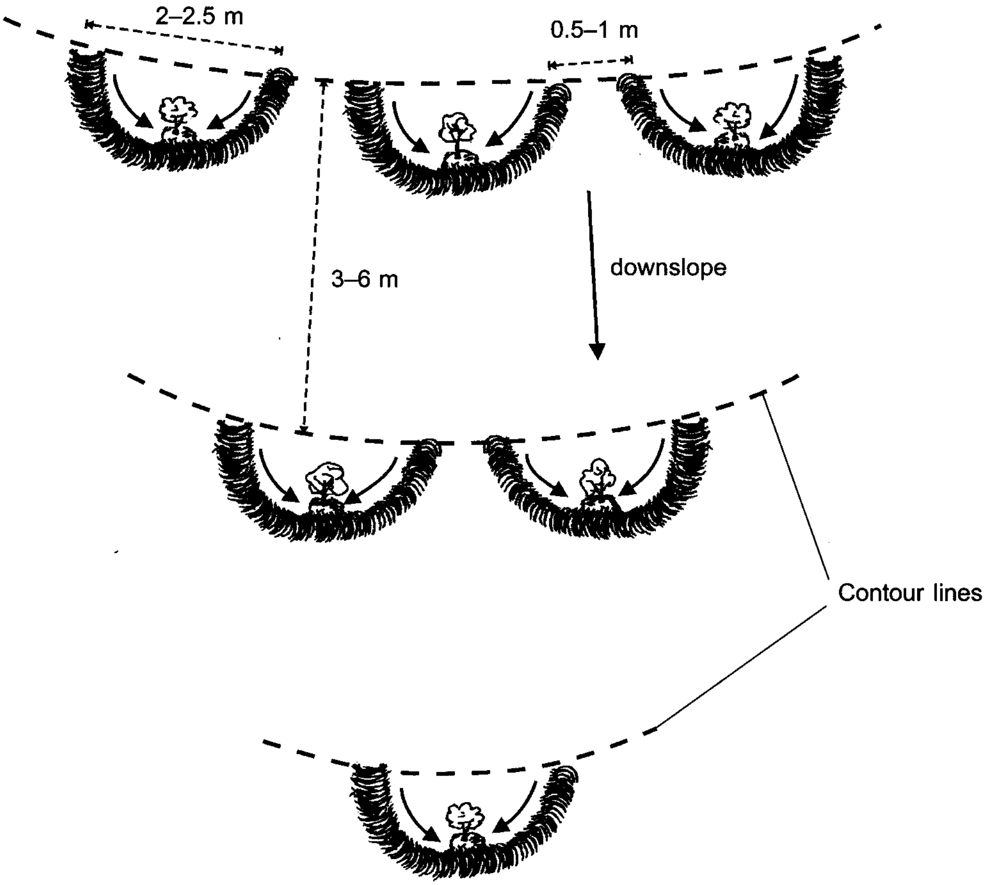
The basins can be made on all types of soil, as long as it is not too shallow or saline. They are used on gentle slopes (less than 2% gradient), but if the bunds are made bigger and are stabilized with grasses, they can be used on up to 5% slopes.



Trapezoidal basin

How to make a microbasin

1 Decide where to plant the trees. Mark a pattern on the ground, staggering the basins on a slope to control runoff.



Layout of half-moon basins

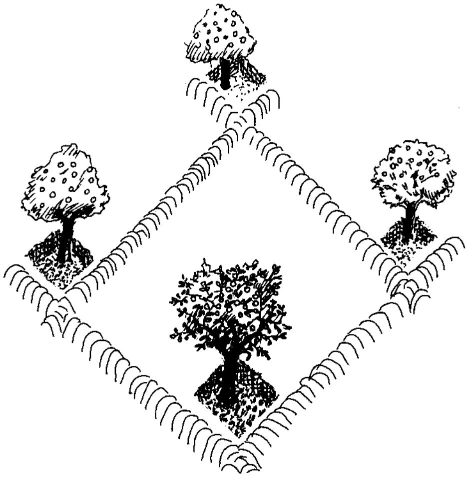
2 Dig a shallow basin around each planting site, piling the soil into a ridge around the downslope side, 15 cm from the edge of the basin. Make the ridge 30–50 cm high and 60–90 cm wide.
3 Plant the seedling (see pages 240 or 243). In dry areas, plant it in the middle of the basin. In moist areas, plant it in the ridge of soil you have built on the lower side of the basin so it does not get waterlogged.

The most critical time for half-moon or trapezoidal basins is just after they are built. Heavy rains can damage them because the bunds are not yet stabilized. Repair any damage quickly to avoid one broken bund causing the next one below it to overflow and break, causing the next to also overflow and break, and so on.

Negarim (diamond) basins

Negarim basins are diamond-shaped basins surrounded by low earth bunds (15–25 cm high). A pit in the lowest corner collects water and allows it to seep into the soil. A tree can be planted in this pit. Negarim microcatchments are used mainly for growing fruit or nut trees and bushes (for fodder). They conserve soil as well as harvesting water. Negarim catchments were first developed in Israel.

Negarim microcatchments are normally between 10 m^2 and 100 m^2 in area, depending on the rainfall in the areas and the type of tree to be planted.



Negarim microcatchment field layout

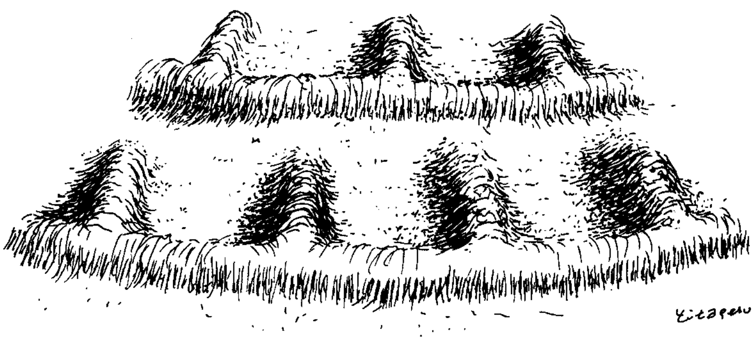
Contour bund microcatchments

Contour bund microcatchments consist of bunds running along the contour every 5–10 m (see page 118). Small earth ties divide the space between the bunds into individual microcatchments. Trenches dug behind the contour bund can prevent overflow when the rain is heavy.

These microcatchments are suited to the Dry Bereha, Dry Kolla and Dry Weyna-Dega zones on slopes up to 5%. They can be used to grow crops or fodder. The soil should be deep enough to allow roots to grow and to store enough water in the soil. On shallow soils, drought-tolerant fodder shrubs could be planted.

Contour bund microcatchments are not suitable for uneven or eroded land, as excess water can overtop the bunds at low spots and break them.

Prevent animals from trampling the bunds and damaging them. Plant grass on the bunds to stabilize them.



Contour bund microcatchments

Cutoff drains

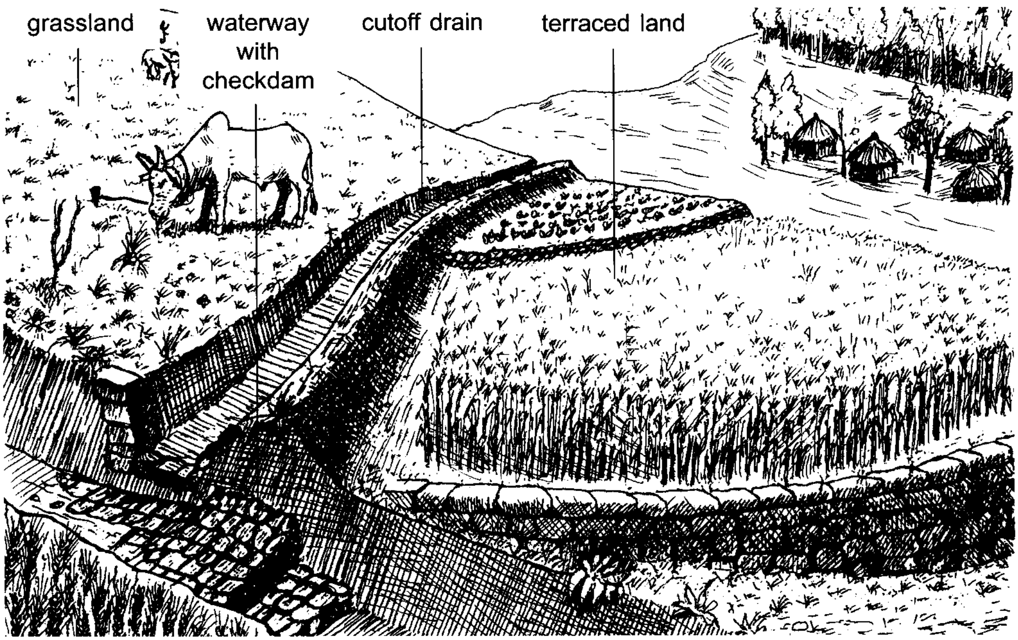
A cutoff drain is a ditch dug across a slope to collect runoff water and divert it to a natural or artificial waterway (see page 139) or to a water storage structure. It protects cropland and other land down the slope. One cutoff drain on a slope is usually enough, but more can be built on long slopes. Cutoff drains should not be more than 400 m long.

Where to use cutoff drains

Agroclimatic zones All agricultural zones except Dry Bereha and Dry Kolla.
Soils All soils are suitable, but it is hard to build a cutoff drain on sandy soils because runoff easily undermines it.
Slopes 3–50%. It is hard to construct cutoff drains on slopes steeper than 50%.

Advantages of cutoff drains

- Cutoff drains take excess water safely away from cropland and help prevent gully erosion.
- Some of the diverted water seeps into the soil, raising the water table and benefiting crops.



A cutoff drain protecting the terraced land to the right from excessive runoff from the grassland to the left

Disadvantages and constraints

- Cutoff drains can cause gully erosion if not properly constructed.
- They take work to build.

How to make a cutoff drain

Before you start, decide on the gradient, width and depth of the drain. The gradient should range from 0.25 to 1%, depending on the amount of runoff in the channel. The drain should allow water to flow easily, but it should not be too steep: do not make it steeper than a 1% gradient.

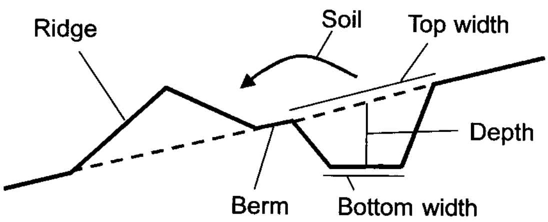
The table below shows the approximate size of cutoff drains for small catchments. The actual size will depend on the catchment and how much runoff is expected. Bigger drains are needed for bigger catchments and if larger amounts of runoff are expected.

1 Starting at the lower end (where you want it to flow into a natural channel or an artificial waterway), mark out the path of the cutoff drain. Use a line level or A-frame to mark out the gradient you have chosen.
2 Dig out the soil and throw it downhill to form a ridge. The ridge stops water from flowing onto the land downslope. Leave a space (called a 'berm') about 15–30 cm wide between the channel and ridge to prevent the soil on the ridge from sliding into the channel.
3 Plant fodder grass on the ridge to make it firm.

If you need to make bigger cutoff drains, ask a specialist for help.

Dimension of hand-dug cutoff drain

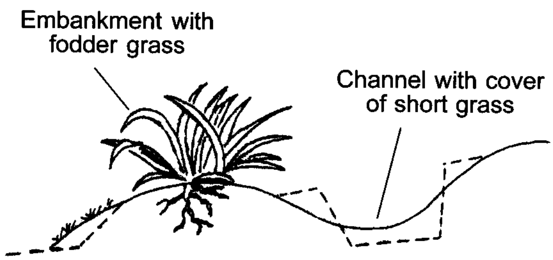
Top width	1.5 m
Bottom width	0.9 m
Depth	0.6 m



Cross section of a cutoff drain

How to maintain cutoff drains

- Repair cutoff drains after heavy rains, and check them every year.
- Regularly remove soil from the drain.
- Maintain the grass on the ridge.



Cutoff drain in use

Waterways

A waterway is a natural or artificial drainage channel that leads water down a slope. It takes runoff water from cutoff drains (page 137) or graded structures (page 124) and carries it to rivers and streams or, preferable, water storage structures.

The width of artificial waterways depends on the steepness of the slope and the amount of runoff in the area.

There are two main types of artificial waterways: grassed and paved.

Where to use waterways

Agroclimatic zones All zones where cutoff drains (page 137) and graded terraces and bunds are used (page 124).

Soils All soils, but care is needed on deeply weathered subsoils.

Slopes 3–50%.

Advantages of waterways

- Waterways take excess runoff safely down the slope, preventing gully erosion.

Disadvantages and constraints

- Poorly constructed waterways can turn into gullies.
- Building waterways is hard work and requires skilled labour.
- If no stones are available, stone-paved waterways cannot be built.

Grassed waterways

Grassed waterways are suitable on gentle slopes if a wide strip of land can be set aside for the waterway. They must be made a year before graded structures (such as

Drainage area and width of grassed waterways

Catchment area of waterway (ha)	Width of waterway (m)		
	0–5% slope	6–12% slope	13–25% slope
1	1.5	1.5	1.5
2	1.5	2	2.5
5	2	3	4.5
10	3	6	9
15	3.5	8	12
20	4.5	12	18

Width and depth of grassed waterways

Top width (m)	Depth (m)
1.5–3	0.3
4–6	0.4
More than 6	0.5

bunds, bench terraces or cutoff drains) that lead water into them are built. This gives time for grass to grow so it prevents erosion along the waterway.

The width of the waterway depends on the size of the area it drains and the slope (see the table on the previous page). The table above shows the relationship between the width of the waterway and its depth.

Graded bunds, bench terraces and cutoff drains should not be too long or they may collect too much water and become eroded. To prevent this, waterways should be built at intervals of about 250 m. The exact spacing depends on the type of catchment, the slope, and the rainfall characteristics of the area.

How to make a grassed waterway

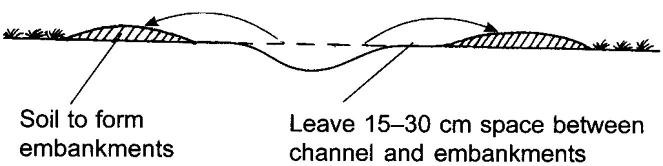
1 Decide where to make the waterway.

2 Decide how wide and deep the waterway should be (see the tables above).

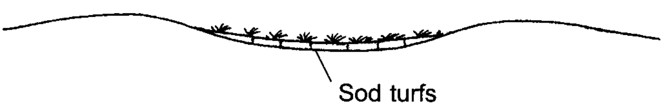
3 Cut out grass sods from the path of the waterway and put them to one side.

Cross-section across grassed waterway

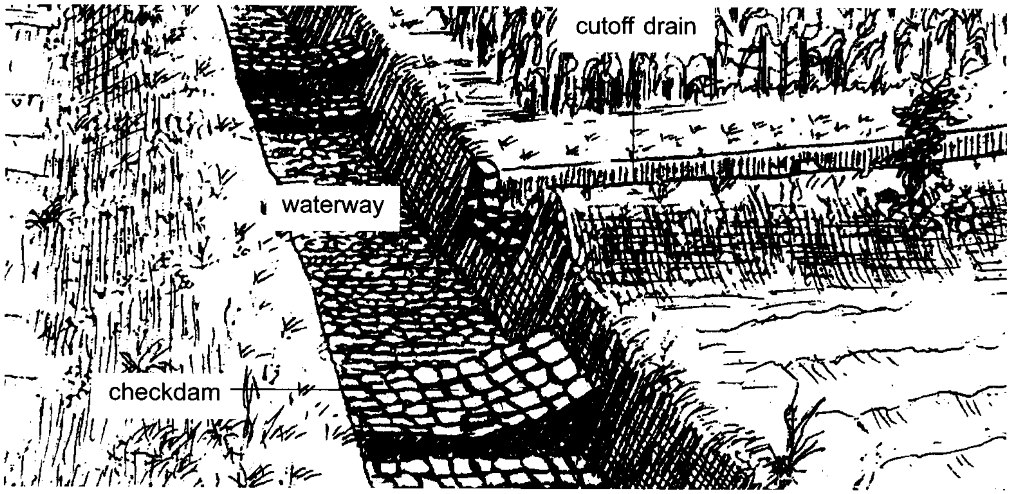
4 Dig a channel along the planned path. Throw the soil on both sides to form an embankment. Leave a 15–30 cm space to stop the soil from sliding back into the channel.



5 Arrange the sods along the channel and on the ridges and fix them in place with pegs.



6 Leave the channel until grass has grown in the channel and on the ridges.



Stone-paved waterway with stone checkdams to prevent erosion where the cutoff drain joins it

Stone-paved waterways

Paved waterways are needed if the waterway is narrow (less than about 1.5 m) and deep (up to 1 m), or if there is not enough grass to cover the waterway.

How to make stone-paved waterways

1 Cut out the grass sods from the path of the waterway and put them to one side.
2 Dig a channel along the path and throw the soil on both sides to form ridges.
3 Collect stones and arrange them along the bottom and sides of the channel.
4 Plant the grass on the ridges.

Combinations

Waterways are useful for all graded structures on cropland and for cutoff drains. Checkdams (page 146) are useful on steeper slopes to prevent scouring, especially if the waterway has little vegetation in it.

How to maintain waterways

- Repair broken stone pavements promptly, for example by replacing stones that get washed away.
- Regularly remove soil from the waterway.
- Keep grass in the waterway short.

Rehabilitating gullies

A gully is formed when several rills join, concentrating water and enlarging to form a channel. As the channel deepens, it undermines its head wall, which retreats up the slope, forming a gully. The gully then widens as the walls are worn back.

The rate of gully erosion depends mainly on the type of runoff from the drainage area, the soil type, the size and the shape of the gully, and the slope of the channel.

Once formed, gullies may erode a wide area, so it is important to control them quickly. Controlling gullies enables water to seep into the soil instead of running off. This recharges the water table, and may make water available in the dry season. Controlling gullies also turns a totally unproductive area into productive land.

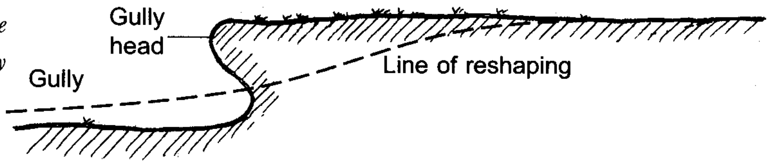
There are three ways of controlling runoff in gullies.

- **Conserving water in the catchment** so it does not reach the gully. There are many ways of doing this, including bunds, trenches, tied ridges, microcatchments and the use of mulch and cover crops (see the sections on these topics).
- **Diverting the water away from the gully** Ways of doing this include cut-off drains and waterways (see pages 137 and 139).
- **Conveying the water safely through the gully.** Methods include reshaping and revegetating (described in this section) and checkdams (see page 146).

Reshaping and filling is useful for small and medium-size gullies. It aims to slow down the runoff and protect the soil surface from further erosion.

Gullies are probably the worst thing that can happen to farmland. They grow quickly, eating away at productive land, making it useless.

Cross section along the length of a gully: the gully head before reshaping



Reshaped gully head with grass carpeting

Where to rehabilitate gullies

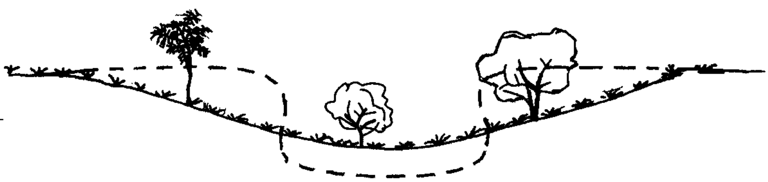
Agroclimatic zones All.
Slopes Gentle slopes, 0–30%.

How to rehabilitate gullies

1 Make cutoff drains and waterways to divert excess runoff away from the gully into another drainage line (see pages 137 and 139).
2 Cut the soil on the steep gully sides and head, and throw it down into the gully to make the slopes gentler.
3 Build checkdams at intervals along the gully bottom (see page 146).
4 Plant grasses on the gully floor and sides, or plant trees or shrub seedlings (4–6 per square metre). You can also pack brushwood into the gully floor, with the large branches downstream and the leaves and twigs upstream. In drier areas, use stones to make steps down the gully floor to prevent erosion.
5 Do not allow animals to graze in or around the gully.

Cross section across gully before rehabilitation

Cross section after rehabilitation



Checkdams

A checkdam is a wall built across the floor of a gully or waterway. It slows down the water flow and stops the gully from getting deeper or wider. It can be made of stones, live or dead branches, metal bars and wooden poles. It has a depression in the middle to allow runoff to flow over it.

Checkdams are useful in small and medium-size gullies. There are three main types: wood, stone, and gabion (wire cages filled with stones).

Where to use checkdams

Agroecological zones All.

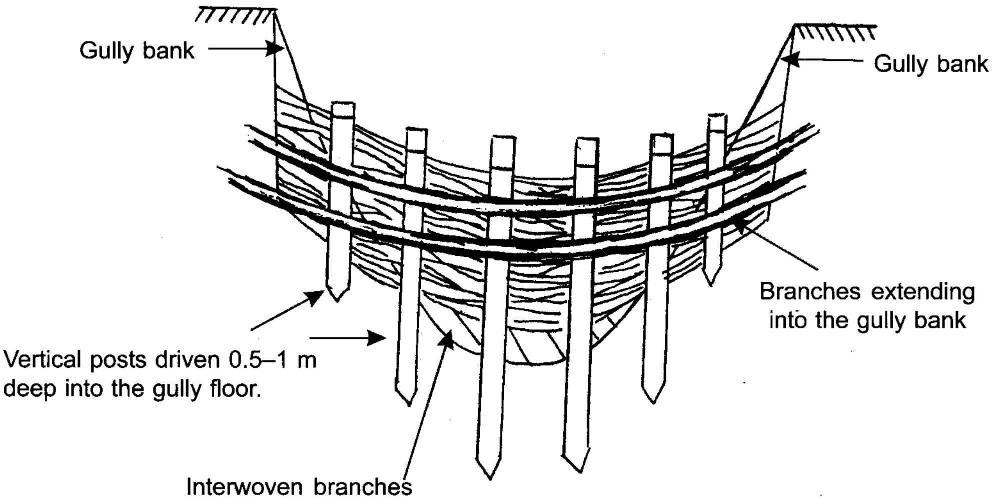
Soils Take care on deeply weathered soils or loosely accumulated deposits because they cannot support structures. In such places you must dig a deep foundation for checkdams.

Slopes All.

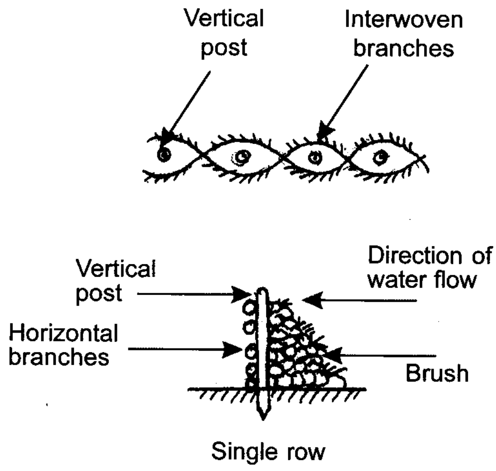
Wooden checkdam

A wooden checkdam is made of small branches and poles woven together and held in place with wire or sisal ropes. It is useful on waterways where the water cannot be controlled with grass alone. The vertical interval between two wooden checkdams should be equal to the height of the dams.

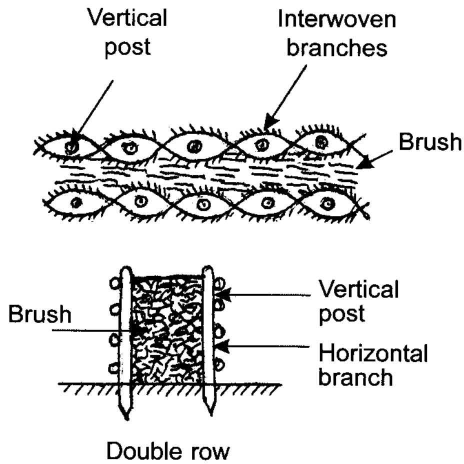
A wooden checkdam can have one or two rows. Double-row dams are stronger but are harder to make.



A wooden checkdam, seen from the front

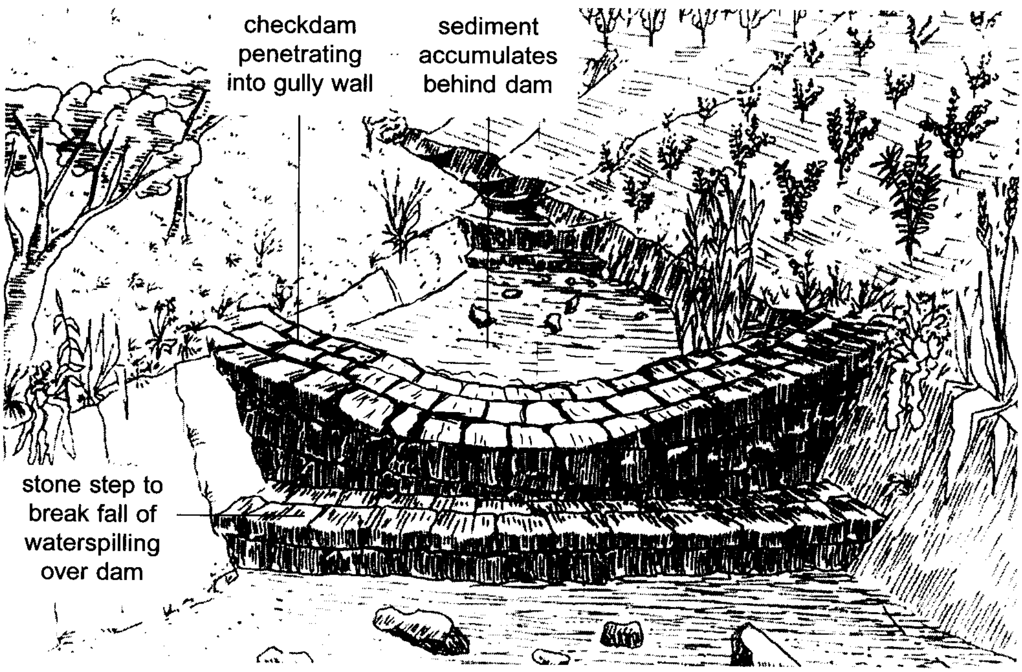


Vertical and side-on views of a single-row checkdam



Vertical and side-on views of a double-row checkdam

1 Make a set of wooden posts, 5–10 cm in diameter and 1.5–2.5 m long. Sharpen one end of each post to make it easy to hammer into the ground.
2 Hammer the posts 0.5–1 m apart, at least 60 cm deep into the floor of the gully. The spacing between the posts depends on the height of the checkdam: the higher the dam, the closer the posts. For a double-row checkdam, make two rows of posts, 50–60 cm between the rows.
3 Weave thinner branches between the posts to form a wall.
4 Dig the branches 50 cm or more into the sides of the gully.



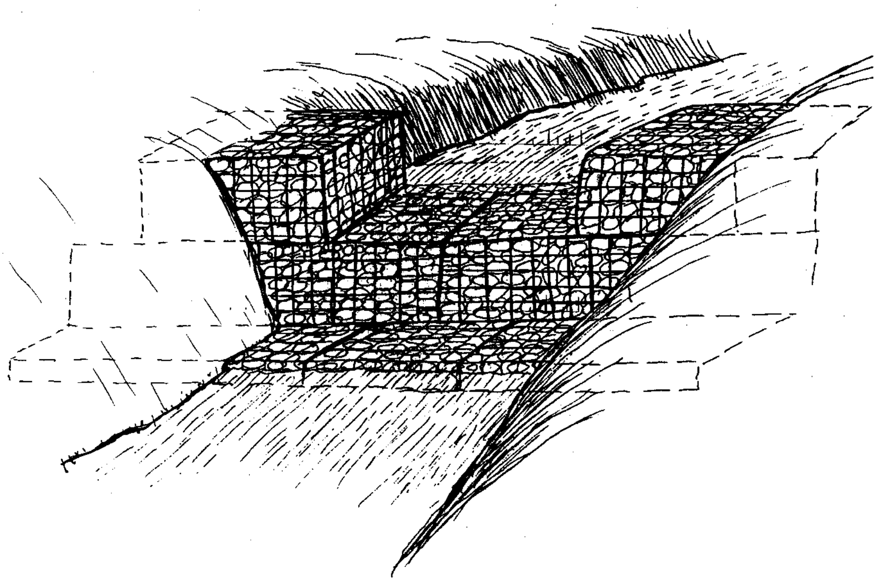
A series of stone checkdams, about 1 m high and 4 m wide. The dam and the step beneath it (designed to break the fall of water spilling over the dam) penetrate sideways into the gully wall. Runoff flows over the centre of the dam. Sediment is deposited behind the dams.

5 Pack brush and other debris behind the wall (or between the rows in a double-row dam).
6 Tie the top of the structure with wire or rope, and anchor it to the ground using brushwood.

Stone checkdams

If the gully floor is rock, use a stone or gabion checkdam instead of a wooden one. Stone checkdams should be built across a gully at 1 m vertical intervals to prevent gully erosion.

1 Dig a trench 40 cm wide and 40 cm deep across the gully, and extend it 40 cm into the gully banks on both sides.
2 Put large stones into the trench you have dug.
3 Use more stones to build a wall 1 m high and 1 m thick. The sides of the wall should be higher than the middle, so that water can flow over the middle.
4 Put more stones against the downstream side of the dam to break the flow of water falling over it (see the illustration above).



Gabion checkdam

Gabion checkdams

Gabions are boxes of wire mesh that are filled with stones. The boxes are put in position then filled with stones, because they are too heavy to move when they are full. Gabions are tough and last a long time. They can be placed where the surface is uneven.

Gabion boxes come in two standard sizes: 2 m long x 1 m wide x 1 m high, and 2 m long x 1 m wide x 0.5 m high.

1 Dig a trench 1 m deep in the gully floor. The trench must be as wide as the gully and should be dug into the wall to stop water from eroding around the sides of the dam.
2 Place gabion boxes into the trench, fill them with stones and tie them with wire.
3 Add another layer of gabions on top to raise the height of the dam. Make the sides of the dam higher than the middle.

How to manage checkdams

- Repair the dams every year, and after heavy rains.

Marking contour lines

Contour lines are horizontal lines across a slope, linking up points at the same elevation. It is important to mark contour lines as precisely as possible when building barriers such as level bunds and bench terraces that protect the soil from erosion. Two simple ways of marking contours are with the line level and the A-frame.

The line level

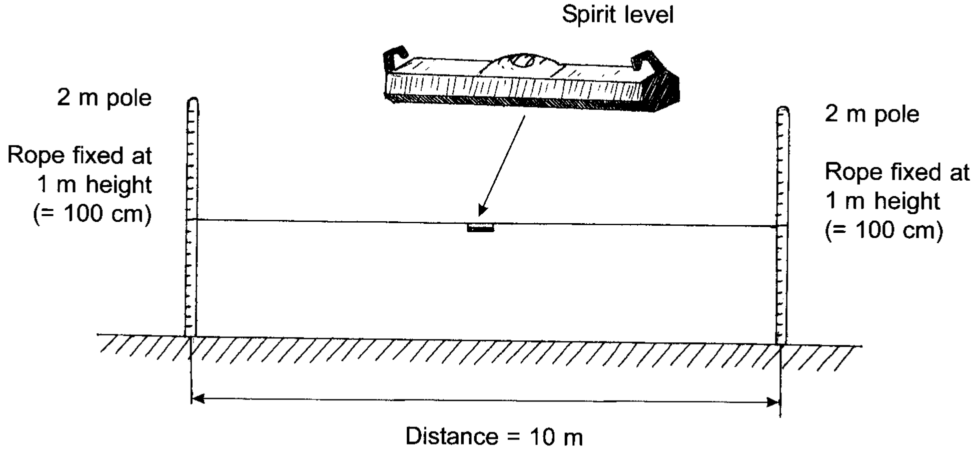
A line level consists of two wooden poles of the same height (usually 2 m) with a string 10 m long joining them. The poles have marks every 10 cm. A spirit level is tied exactly in the middle of the string.

You will also need sticks or pegs to mark the contour on the ground (about 20 pegs per 100 m), and a stone or hammer to drive the pegs into the ground. Three or four people are needed to mark contours using a line level.

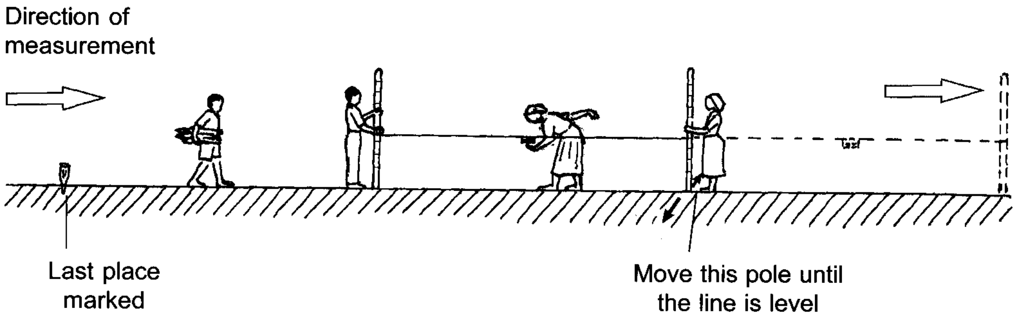
Using a line level to mark contours

1 Always start laying out contours at the top of the slope (not the middle or bottom), or immediately below the cutoff drain (if you have dug one). Drive a peg into the ground where you want the first contour to begin.

2 One person holds the first pole upright at this first peg. The other person walks roughly level with the other pole until the string is tight. The third person checks the spirit level in the middle of the string, and directs the second person to move



Line level



Using a line level

the pole up or down the slope until the bubble is exactly in the middle of its run (meaning the line is level). Drive a peg into the ground next to the second pole.

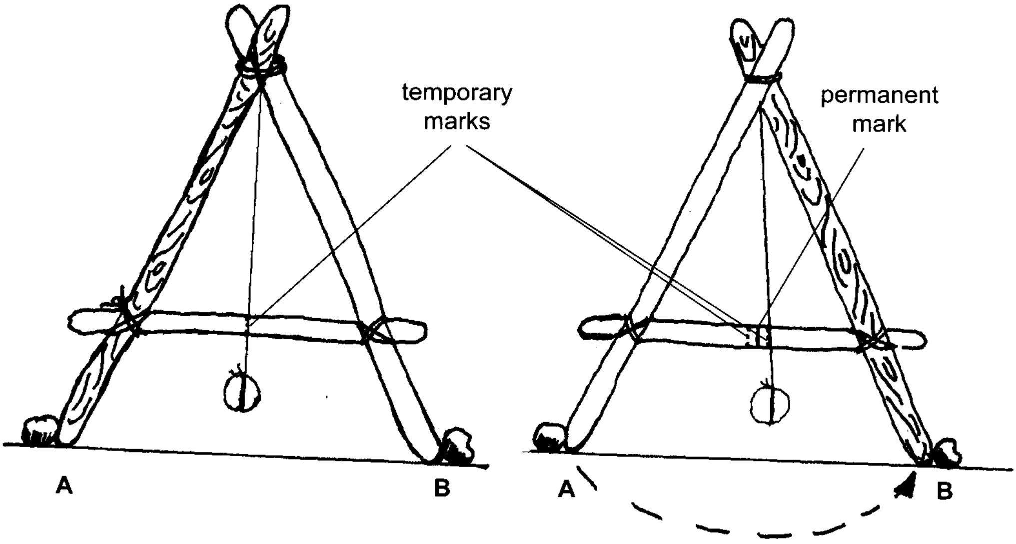
3 The two people holding the poles then both move forward until the first pole is at the second peg. Keeping the string tight, the second person again moves his or her pole up or down the slope until the line is again level. Drive a third peg into the ground here. Repeat the process until the whole contour line is marked out.
4 To start a second contour line further down the slope, find a starting point by measuring the vertical interval you want (see page 155). Then repeat the process for the new contour line.

In difficult topography, it might be inconvenient to measure 10 m at a time. Try using half the length of the string (5 m).

The A-frame

An A-frame is made of three poles fixed together like a letter A. It can be made from local materials. You will need about 2 m of strong string, a stone to act as a weight, 2 wooden poles with flat ends 3 m long, 1 pole about 2 m long to use as a crosspiece, a hammer and nails, and a knife.

1 Take the two 3 m poles and fix them together at the top. Fix the 2 m pole horizontally about 1 m from the bottom to form an *A* shape. Use nails rather than (or as well as) string to fix the poles if you can: it makes the A-frame more rigid and less prone to errors.
2 Tie one end of the string to the stone, and hang it from the top of the *A*. The stone should hang freely about 15 cm below the crossbar.
3 Stand the A-frame on a level piece of ground. Make a small, temporary mark on the crossbar where the string hangs past it.
4 Turn the A-frame round so that each foot stands exactly where the other had been. Make a second temporary mark on the crossbar where the string hangs past it.
5 Mark a large, final mark midway between the two temporary marks. If the string hangs against this mark, the two feet of the A-frame are exactly level.

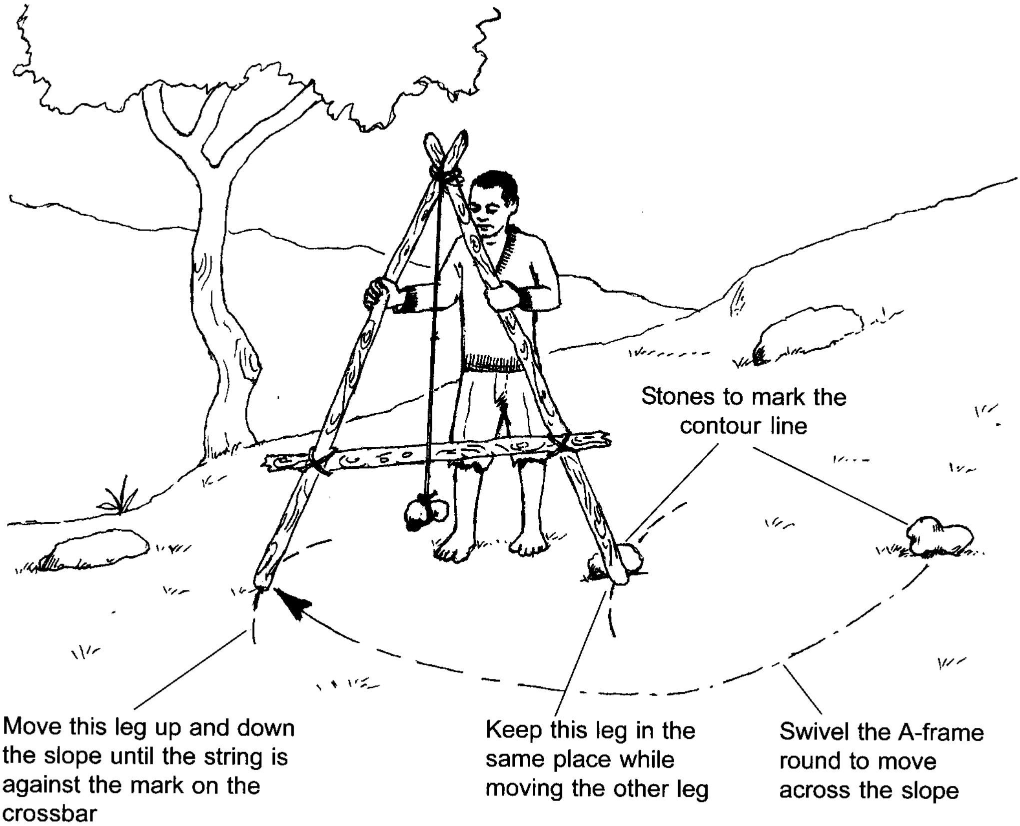


Calibrating an A-frame. Make a small mark on the crossbar where the string touches it. Then turn the A-frame round and make another small mark where the string touches. Make a permanent mark between the two.

Using an A-frame to mark contours

Use the A-frame only on calm days, since the wind disturbs the string and can give the wrong measurements.

1 Use a peg to mark the starting point. Put one of the feet of the A-frame next to it. Do not put the feet in holes, depressions, or on stones, ridges, humps or anthills.
2 Holding this leg in place, move the other one around until the string hangs precisely over the mark on the crossbar. Hit a peg into the ground here to mark it.
3 Hold the second leg in place, and pivot the first leg around until the string hangs exactly over the mark on the crossbar again. Drive another peg into the soil at this point.
4 Continue pivoting along the contour, marking the locations as you go, until you reach the end of the field.
5 Then move down the slope to where you want to begin the next contour line, and repeat steps 1 to 4.



Using the A-frame. One person can mark contour lines using an A-frame.

Marking graded lines

Graded lines are lines of constant gradient (usually 1% or 2%), going across a slope. They are used to plan conservation structures, such as cutoff drains and graded terraces, that need to slope gently so they allow water to drain away.

Graded lines can be marked out using a line level or an A-frame.

Preparing a line level to mark graded lines

You can use the same line level as for marking contours (see page 148), only you have to fix the string differently. The string on a standard line level is 10 m long.

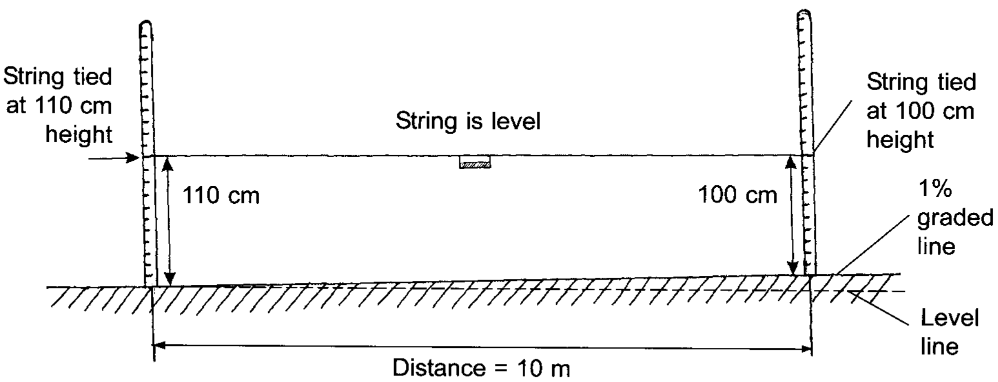
First, decide the gradient you want to mark. For a 1% gradient, the height difference over 10 m equals 10 cm. Tie the string on one pole at a height of 110 cm (1.1 m). On the other pole, tie it at 100 cm (1 m). When the bubble is at the centre of the spirit level, the string will be level, but the bottom of the second pole will be 10 cm higher than the bottom of the first pole.

For a 2% gradient, tie the string at 120 cm (= 1.2 m) on the first pole, and the other end at 100 cm.

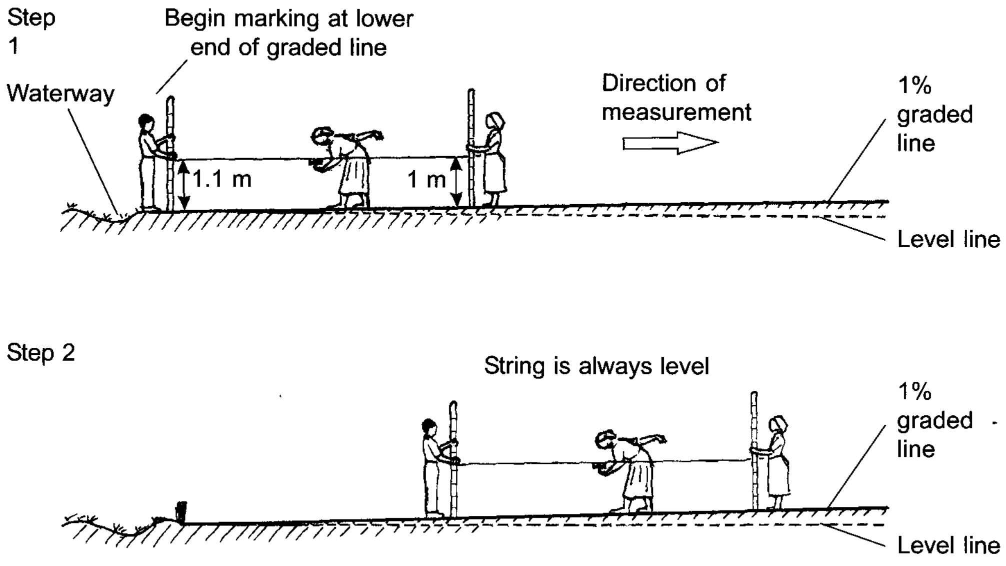
For a 0.5% gradient, tie the string at 105 cm on the first pole.

Using a line level to mark graded lines

1 Start marking graded lines at their lower end – for example, where you want a graded drainage line to meet a natural stream. Mark this place with a peg, and stand the pole with the string tied higher up (e.g., at 110 cm) here.
2 Move the other pole (tied at 100 cm height) roughly level and slightly upslope until the string is tight (10 m away).



A 1% graded line



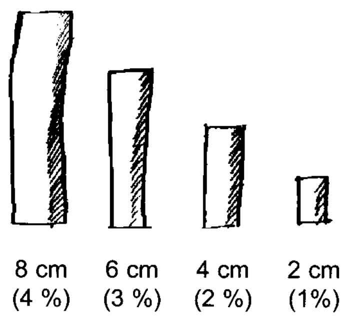
Marking 1% graded lines on the ground

3 Check whether the bubble is in the centre of the spirit level. Move the second pole up or down the slope until the bubble shows the string is exactly level. Mark this point with another peg.
4 Move both poles forward until the first pole is at the second peg (this pole must always be lower down, nearer the start of the line). Move the second pole until the string is tight, then move it up and down the slope until the string is level. Mark this point with a third peg. Repeat this process until you have marked out the whole graded line.
5 To start a second graded line, find a starting point by measuring the vertical interval you want (see page 155). Then repeat the process for the new line.

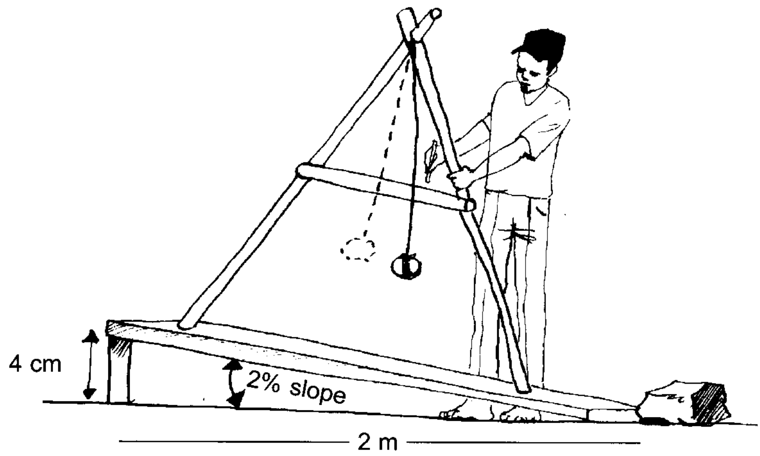
Preparing an A-frame to mark graded lines

To use an A-frame to mark graded lines, you must mark on the crossbar the point where the vertical string touches the crossbar when the A-frame stands on a slope of 1%, 2%, and so on.

You will need a plank of wood at least 2 m long. Make a mark on the plank exactly 2 m from one end. Cut several small blocks of wood to different lengths: 1 cm, 2 cm, 4 cm, 6 cm, and so on.



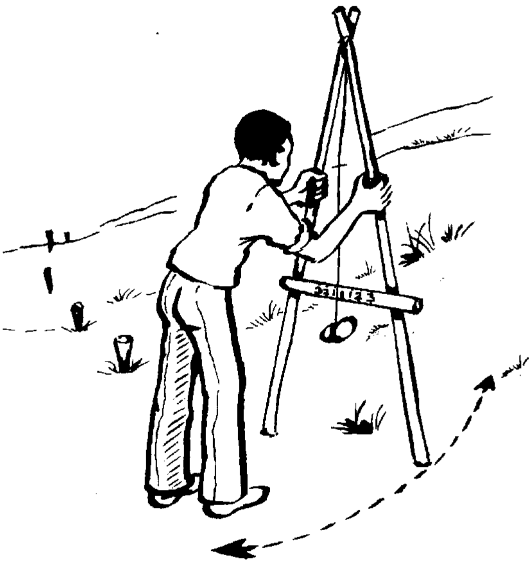
1 Put the plank on a level piece of ground (use the A-frame to check that it is level).
2 Put the small 2-cm block under the plank at exactly the 2-m mark. The plank should now slope at a gradient of 1%, since 2 cm is 1% of 2 m.



3 Stand the A-frame on the plank, being careful not to move the plank or the small block under it. Mark the point on the crossbar where the string touches it and write a '1' next to the mark.
4 Turn the A-frame around and again mark the point on the crossbar where the string touches it. Write a '1' here too.
5 To mark a 2% gradient, replace the small 2-cm block with the 4-cm block. Repeat steps 3 and 4, marking the points where the string touches the crossbar with a '2'.
6 To mark an 0.5% gradient, you can use the 1-cm block. For a 3% gradient, use the 6-cm block.

Using an A-frame to mark graded lines

1 Start marking graded lines at their lower end (as with the line level). Mark this place with a peg, and stand one leg of the A-frame here.
2 Move the other leg slightly upslope and swivel the A-frame until the string hangs at the mark for the gradient you want (e.g., against the '1' nearest the lower end of the grade. Mark where the second leg stands with a peg.
3 Swivel the A-frame round the second leg, until the string touches the '1' mark (always use the mark closest to the lower end of the graded line). Mark this place with a peg. Repeat this process until you have marked out the whole graded line.



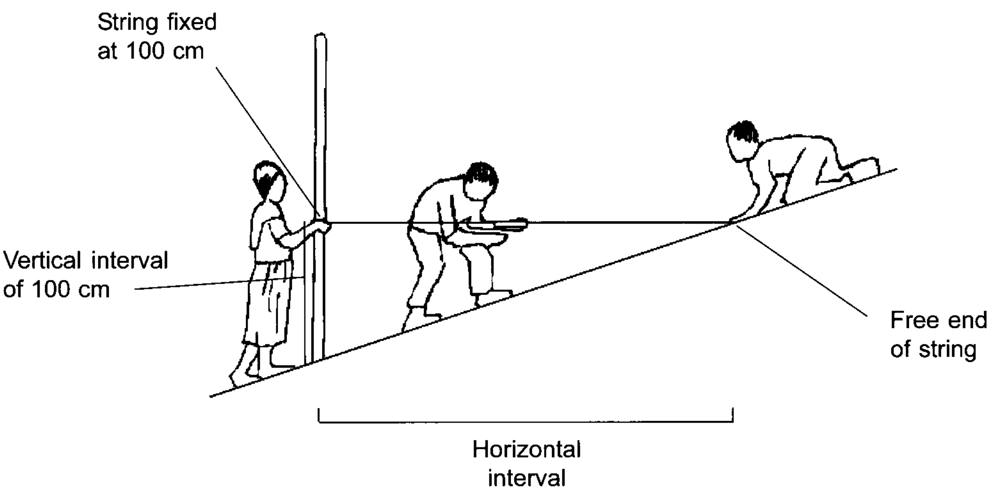
Measuring vertical intervals and slope gradients

A 'vertical interval' is the distance in height between two objects, such as two terraces or contour bunds. Conservation structures should be built at a small enough vertical interval to prevent erosion.

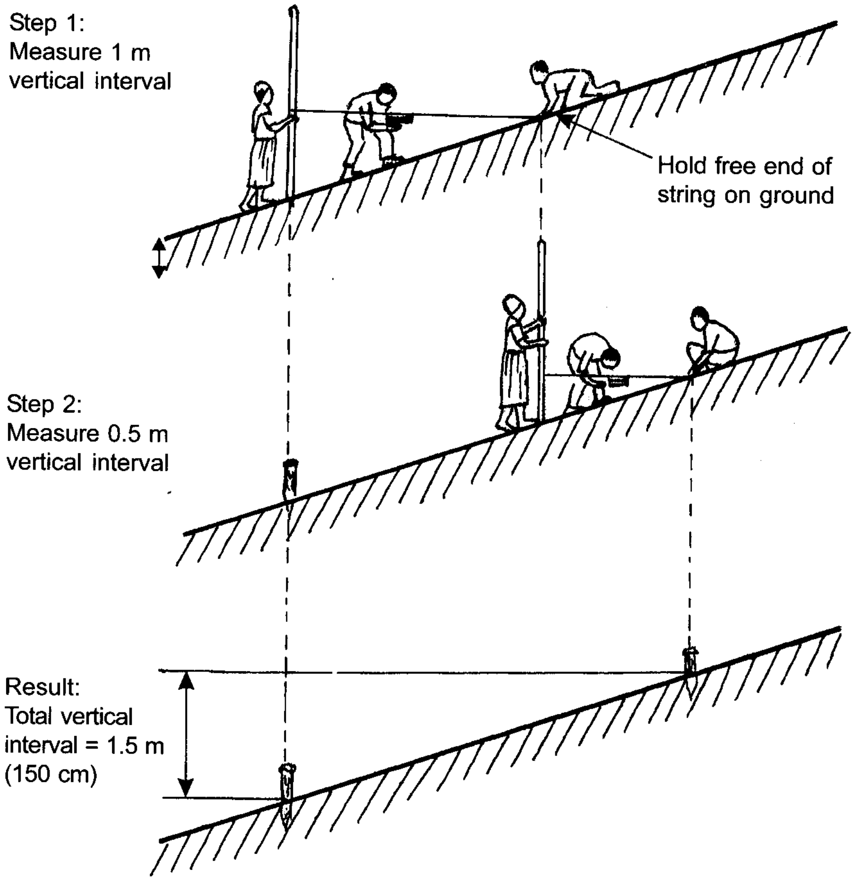
Measuring vertical intervals with a line level

1 To measure a vertical interval of 1 m, fix the string on one pole of the line level at 100 cm (1 m). You can untie the string from the other pole; you will not need it.
2 Have the person with the free end of the string hold it on the ground at the top of the slope.
3 A second person with the pole and string attached moves straight down the slope. The first person pays out enough string to keep the string taut. The third person watches the bubble in the spirit level.
4 When the bubble is in the centre of its run, the string is level. The pole is exactly 1 m below the free end of the string. Mark these two places with pegs or stones.

On gentle slopes, the string may be too short. Try measuring the vertical interval in two steps of 50 cm each.



Measuring a vertical interval of 100 cm using the line level



Measuring a vertical interval of 1.5 m using a line level.

To mark a larger vertical interval of, say, 1.5 m, you can first measure a 1 m vertical interval, then one of 0.5 m.

A rule of thumb for spacing structures such as checkdams and bench terraces:

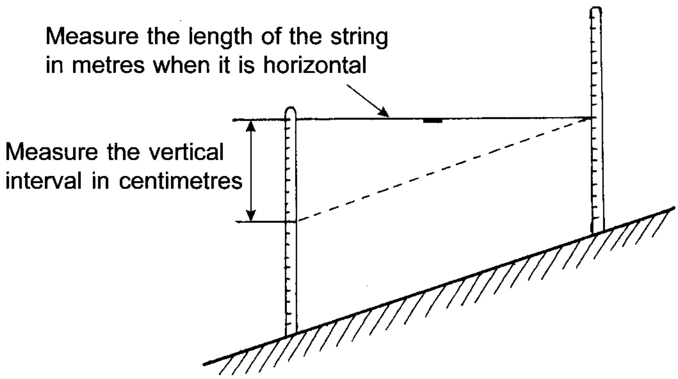
- On slopes less than 15%, use a vertical interval of 1 m.
- On slopes steeper than 15%, use a vertical interval 2.5 times the depth of the soil. For example, if the soil is 50 cm deep, space checkdams at a vertical interval of 125 cm.

Measuring slope gradients with a line level

1 Measure a convenient vertical interval (in centimetres) of any distance (see previous page).
2 Measure the horizontal interval (the length of the horizontal string) in metres.
3 Divide the vertical interval by the horizontal interval.

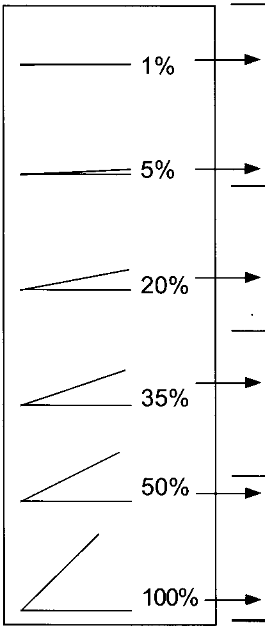
$$\text{Slope in \%} = \frac{\text{Vertical interval in centimetres}}{\text{Horizontal interval in metres}}$$

Slopes can also be measured in degrees, or as a ratio. See the table below to convert from one to the other.



Measuring the slope gradient using line level

Slope conversions



Percentage	Degrees	Ratio
0.5%	0.3°	1 : 200
1%	0.6°	1 : 100
2%	1.1°	1 : 50
3%	1.7°	1 : 33
5%	2.9°	1 : 20
10%	5.7°	1 : 10
15%	9°	1 : 6.7
20%	11°	1 : 5
25%	14°	1 : 4
30%	17°	1 : 3.3
35%	19°	1 : 2.9
40%	22°	1 : 2.5
45%	24°	1 : 2.2
50%	27°	1 : 2
60%	31°	1 : 1.7
80%	39°	1 : 1.3
100%	45°	1 : 1

6

Managing water

Rain that falls on the ground can do one of three things: it may evaporate quickly, it may seep into the soil, or it may run off the surface.

- If the water evaporates, it is lost into the atmosphere (though it may fall again somewhere else as rain).
- If the water seeps in, it may stay in the soil where plant roots can reach it. Or it may filter further down into the ground. This water can be reached by plants with deep roots, or it may reappear at the surface lower down as a spring. People can tap this groundwater by digging wells.
- Water that runs off the surface may dislodge small soil particles and carry them away, causing erosion. Most of this water ends up in streams and rivers, and is lost to agriculture at the site (though perhaps it may be used downstream).

Water harvesting 'harvests' water from a 'catchment area' – somewhere that produces runoff during rains, such as a roof, an area of ground, or a stream. It then concentrates this water where it is needed – in a field, pond or basin, where it can be used for farming or domestic use.

There are two major types of water harvesting:

- **Rainwater harvesting** This harvests runoff from roofs or the ground.
- **Floodwater harvesting** This involves diverting and storing runoff from a water course.

Catchments can be divided into:

- ***Micro*catchments** Runoff flows directly into the planting area (see page 133).
- ***Macro*catchments** A channel connects the catchment with the planting area.

This chapter describes various techniques of using macrocatchments to harvest water. It also covers several useful methods to store water in tanks, and how to use it for irrigation.

It is difficult to separate water management from soil and water conservation. Many of the methods described in Chapter 5 are also useful for collecting and conserving water.

Macrocatchments

Macrocatchments cover a much larger area than microcatchments (page 133). In macrocatchments, water is collected in a catchment, and then is led to a separate place where it is stored and used. The catchment area is usually several times larger than the area where the water is used, and may be hundreds of metres away.

This section covers the following macrocatchment techniques:

- Floodwater harvesting (spate irrigation)
- Small earth dams
- Subsurface dams
- Farm ponds
- Rock catchments.

Because these techniques handle large amounts of water, designing and building them need special skills. It is easy to make a mistake, waste time and money, and lose credibility with the local people. It is best to call on a specialist for help if you are considering using any of these methods.

Where to use macrocatchments

Agroclimatic zones All zones where water is needed.

Soils All soil types. The best form of macrocatchment depends on the type of soil. See each section below for details.

Floodwater harvesting

Floodwater harvesting uses dams, weirs and channels to divert water from a flooded river into the fields. It is also called 'spate irrigation' because it collects water only when the river is high ('in spate'). It is feasible in areas where there is enough rain in the upper reaches of river courses that are normally dry. In such areas, 2–4 floods can provide enough life-saving irrigation for drought-tolerant crops such as sorghum, millet and safflower.

The water in the stream bed can be harvested either by spreading it within the stream bed, or by diverting it to fields outside the bed. The catchment area is usually 10 times larger than cultivated area (or more). Some catchments may be several square kilometres. Floodwater harvesting can be used on flat land or on slopes up to a 5% gradient.

Local organizations, or 'water-user groups', normally manage the equitable allocation of water among users. These groups are responsible for resolving disputes and organize labour to maintain canals and dykes after heavy floods. As soon as upstream users have diverted sufficient water to irrigate their plots, they should release water to users downstream.

Advantages of floodwater harvesting

- Floodwater harvesting is relatively cheap as it depends on locally available materials and local labour. The main costs are for building the dam or weir, the bunds, and the channels to carry water to the fields. The cost is about 3000 birr (US$ 360) per hectare (in 2003).

Disadvantages and constraints

- Only experienced farming communities, assisted by trained specialists, practise traditional floodwater irrigation.
- Rivers sometimes change their courses. This may prevent floodwater from being diverted to the fields, forcing the farmers to abandon their plots.
- It is laborious to construct and maintain the structures, and they can be damaged by heavy floods.

Small earth dams

People in several parts of Ethiopia use small dams and ponds to store water for household use and livestock. However, building these needs skills and money, so they are not common.

An earth dam consists of a main dam with a waterproof fill at its core, a reservoir area, a spillway to release excess water, and an outlet to carry water to the irrigation canal.

Small earth dams are generally suited to the Weyna-Dega and Kolla zones. In the higher altitude Dega zone, irrigated crop production is limited, and the watershed areas are smaller.

A small earth dam is feasible where there is enough rainfall (at least 500 mm a year), and where enough runoff can be harvested from the catchment area. The highlands offer suitable sites to build dams. Protecting the watershed is important to prevent the reservoir from silting up.

Dams are generally not feasible in the lowlands because the topography is too flat. In semi-arid areas, too much water evaporates. In the Bereha zone (below 500 m), much larger watersheds are required to gather water, and the evaporation losses are very high.

Advantages of small dams

- Small dams provide a reliable source water for domestic use, livestock watering and small-scale irrigation.

Disadvantages and constraints

- There is often insufficient information to estimate runoff from the catchment.

Underestimating the peak amount of water may mean the spillway is too small, allowing water to flow over the top of the dam and destroying it.

- Using the wrong materials may mean the dam leaks, or is too weak. If a dam collapses, it can cause severe damage, especially if it is located above a road or houses.
- Silting may shorten the useful life of a reservoir.
- Seepage (resulting in waterlogging) may destroy productive land.
- Standing water offers a home for snails (that carry bilharzia disease) and mosquitoes (malaria).

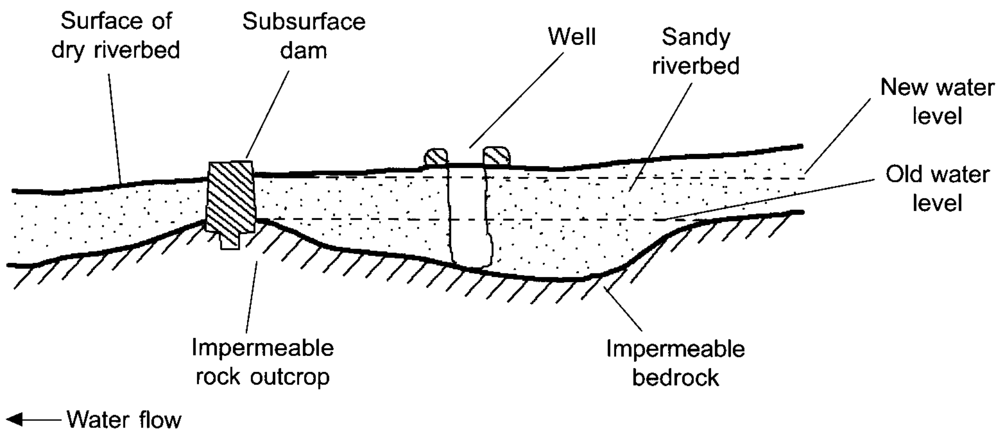
Subsurface dams

Seasonal riverbeds often have water flowing underground, even during the dry season.

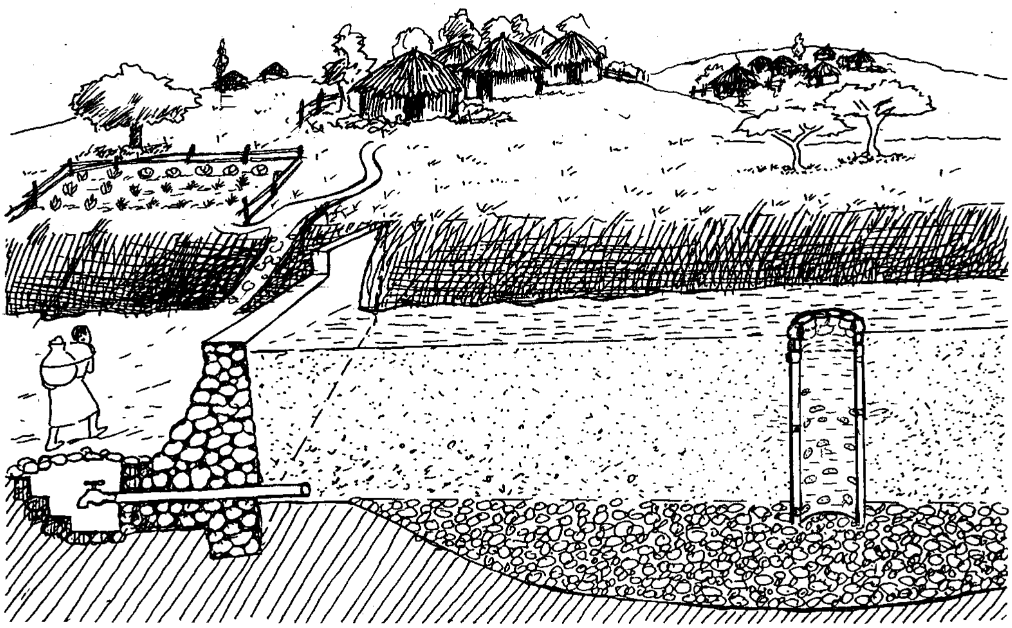
A subsurface dam is built below the ground in such a riverbed to block the water flow. The water trapped in the sand behind the dam can be used for domestic use and small-scale irrigation. Subsurface dams are usually small – normally less than 50–60 metres wide.

The best place for a subsurface dam is where the riverbed is about 15 m wide and consists of coarse sand or gravel, overlying impermeable bedrock or clay about 2.5 m below the surface. Such places are generally found in the foothills in lowland areas, below 1,500 m above sea level. Where the underlying bedrock forms a natural outcrop beneath the surface, it will trap water behind it. Building a subsurface dam on top of this outcrop will increase the amount of water that is trapped.

To build a subsurface dam, it is necessary to dig out the sand in the riverbed, down to the bedrock. The dam can then be made of clay, masonry or concrete to form an impermeable barrier. The dam should not be more than 40 cm above the ground surface. Most of the dam is buried underground.



Section along a dry river bed, showing a subsurface dam



A cross-section showing a typical sand dam construction.

The water that collects behind the dam can be tapped from a well and handpump behind the dam, or by a pipe running through the dam downstream.

Sand dams

A sand dam is like a subsurface dam, but is built higher so it traps sand behind it. The water that accumulates in the sand can be collected and used. Sand dams are most appropriate for watercourses in the lowlands, particularly those that come from steep, rocky areas that carry a lot of course sand.

Sand dams are built in the same way as subsurface dams, except that the dam is built higher. It must be stronger than a subsurface dam, because it must support the weight of the sand and water on one side.

Advantages of subsurface dams and sand dams

- Very little water is lost to evaporation because it is stored in the sand.
- There is no problem of siltation, because seasonal floods pass over the reservoir that is already filled with sand.
- Water stored below the surface is not exposed to contamination as in open ponds or dams.
- If a sand dam is built in stages (not more than 30 cm higher before each flood), it will trap coarse sand (which holds a lot of water), not fine silt (which holds less

water). This coarse sand can be dug out and used for construction or sold. The dam can then be raised (by not more than 30 cm) before the next flood.

Disadvantages and constraints

- Choosing the right site for subsurface dams and sand dams is difficult.
- A poor design and poor construction may lead to failure – the water may seep away, or the dam may collapse.

Farm ponds

A pond can store water for dry season needs (usually for livestock or irrigation). They can be dug into the ground, or made by constructing an embankment. The earth that is excavated is used to build the sides of the pond. Excavated ponds are becoming important in many parts of Ethiopia where water is scarce in the dry season.

Many ponds fail because they lose water too quickly through seepage, or because they silt up. The location must be chosen carefully. It must have suitable soils and be free of excessive silting.

Under the Ethiopian conditions, it is economical to build small ponds to supply water during the wet season and perhaps for a month or two afterwards. One cubic metre of stored water costs about 3–4 birr (in 2003) (about US$ 0.40).

How to select a site for a farm pond

Locate your farm pond where the soil is not too sandy. Soil with too much sand or gravel will not hold water, and the banks will not be strong. The soil should have enough clay in it. Clay soil holds water very well. Here are two tests to see if the soil is good for building a pond.

Test 1

Take a handful of soil and squeeze it into a ball. Throw it into the air and catch it.

- Bad soil with too much sand or gravel in it will not stick together. The ball will fall apart.
- If the ball sticks together well the soil may be good, but you cannot be sure. Use Test 2 (below) to be sure that the soil is good.

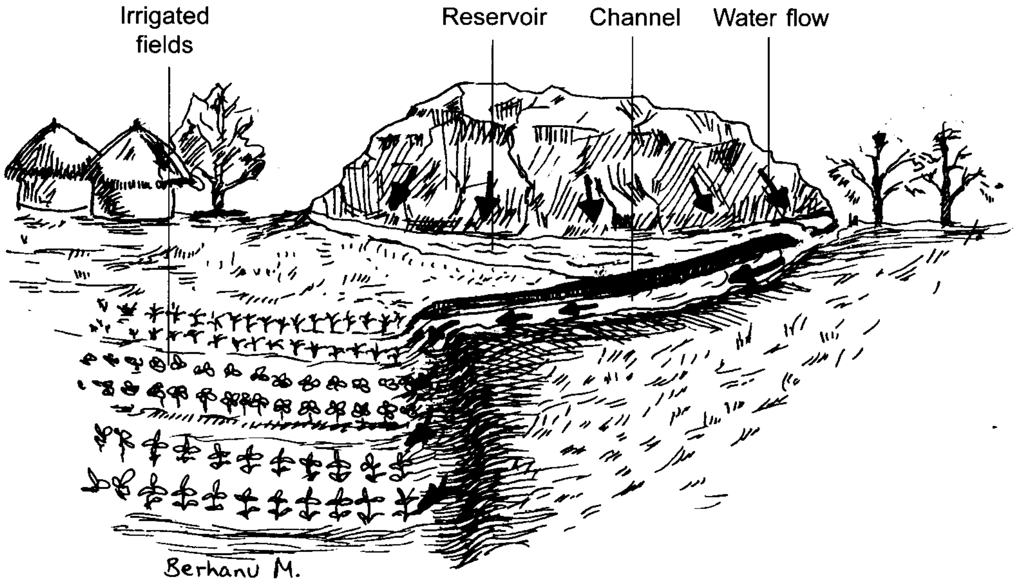
Test 2

1 Dig a hole 1 m across, the same depth as you want to make the pond.

2 Early in the morning fill it to the top with water. By evening some of the water will have sunk into the soil.

3 Then fill the hole completely with water again. Cover the hole with leafy branches or other materials to protect it from the sun.

4 The next morning, if most of the water is still in the hole, the soil will hold enough water to build a pond there.



Rock catchment

Evaporation is a major problem, especially if the pond is exposed to the wind. Small, deep ponds are better than large shallow ones, because they lose less water to evaporation.

Seepage can be reduced by lining the bottom with compacted clay.

Rock catchments

Large outcrops of solid rock exist is many areas. These can be used to harvest a lot of rainwater for household use and to water livestock.

The rock outcrop must be large enough, and all the cracks in its surface must be sealed to prevent water from escaping underground. A bund made of stones and cement is built around the outcrop to channel water into a storage tank or small dam.

The cost of water harvested in this way depends on many factors. The cost is about 250 birr (about US$ 30) per cubic metre (in 2003).

Water tanks

All water harvesting systems need somewhere to store the water. This may be a pond or reservoir or in the soil itself (see pages 160–5), or in specially built tanks. This section covers water tanks.

Tanks may store water collected from ground surfaces, from rooftops, or from springs, streams and rivers. The stored water can be used for:

- Irrigating crops (during the dry period following the rainy season, for instance).
- Supplying water for livestock.
- Household needs.
- Any combination of these.

Water tanks may serve individual households, groups of households, or the whole community. In general, larger tanks cost more than individual structures, but are cheaper per cubic metre of water stored. They also are harder to build and manage.

Where to use water tanks

Agroclimatic zones All.

Soils The kind of soil in the catchment area is important. In the best catchments, the soil is clay or loamy, and forms a crust during hard rain, producing a lot of runoff. If the soil contains a lot of sand, look for another surface (a large rock or a rooftop) to collect runoff.

Planning a water tank

Before starting to plan a water tank, it is important that beneficiaries are behind the idea – it should be theirs to begin with. They should help decide what type of tank to build because they will be responsible for maintaining it. The people may even build the tank themselves.

Here are some questions to ask the people (note, this is not a comprehensive survey, but a general guide):

- How available are other water sources – such as springs, wells and rivers – for household needs, watering animals and irrigation?
- What are the major problems in getting enough water? (Possibilities: distance to source, water quality, other factors.)
- How willing is the household or the community to contribute labour and local construction materials? (They may even provide cash for some or all of the needed materials.)
- Is there land available to build the tank? How about for a small irrigated plot?

- What will the water be used for? (Possibilities: household, livestock, small-scale irrigation, or all of these). How much water will be needed each month? (See the box on page 168.)

You may find that existing water sources can be improved, avoiding the need to build an expensive tank.

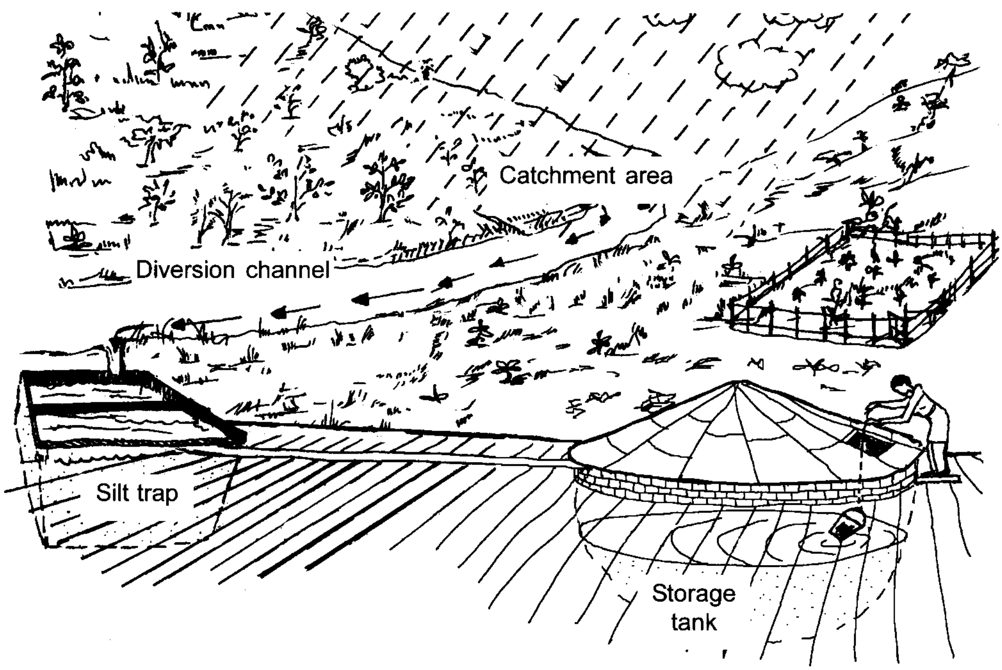
All water tanks have four parts: a catchment area, a channel (or gutter and pipes) to carry water from the catchment to the tank, a silt trap, and the storage tank itself.

Catchment areas

The catchment area may be a natural surface (a rock outcrop or hillside) or artificial (roof, football pitch, road). Rainwater falls on the surface and drains towards a single point.

Consider the following when selecting a catchment area:

- The catchment must collect enough water to supply the users' needs (see the box on page 169 for how to estimate this).
- It must be easy to divert the water to the tank.
- The catchment must be located away from sources of pollution (toilets, animal sheds), and must be protected from contamination. Fence livestock out, especially during the rains.
- The catchment must generate as little sediment as possible. Use suitable soil conservation measures to reduce the amount of silt that is carried into the tank.



Main parts of a household water harvesting and storage system (showing a hemispherical tank)

How much water does a household need?

When planning a water tank, it is important to know how much water will be needed so you can make the tank the right size. Households use water for drinking, cooking, bathing, washing, and for small animals. The amounts depend on many factors. For much of Ethiopia, use the following figures as a rough guide:

- **People** — 15 litres per person each day
- **Cattle** — 25 litres per animal each day
- **Lactating cows** — 25 litres per animal each day, plus 5 litres for each litre of milk produced
- **Horses and donkeys** — 20 litres per animal each day
- **Sheep and goats** — 10 litres per animal each day
- **Poultry** — 15 litres per 100 birds each day

Multiply these figures by the number of people (or each type of animal) to get the total, needed by the household each day. Add about 20% to allow for losses such as evaporation and seepage.

Example

A household of five people keeps two oxen and two goats. How much water do they need in a day? How much in a month?

- **People** 5 x 15 = 75 litres each day
- **Oxen** 2 x 25 = 50 litres each day
- **Goats** 2 x 10 = 20 litres each day

Total water needed each day = 75 + 50 + 20 = 145 litres each day

Add 20% to allow for losses: 145 x 1.2 = **174 litres** each day

Amount needed in one month= 174 x 30 = **5,220 litres** per month

Amount needed per year = 5,220 x 12 = **62,640 litres** per year or about 63 m^3.

Diversion channels

The diversion channel leads water from the catchment area to the silt trap and the tank. It should be made of compacted earth, or lined with cement. It should have a very gentle gradient to prevent it from being damaged.

If the catchment area is a rooftop, fix a gutter to carry water from the roof into the silt trap and tank.

Silt traps

A silt trap is a small pit used to catch sediment carried by the water. It prevents the tank from becoming clogged. The size of the trap depends on the amount of runoff

How much water will a catchment produce?

The amount of runoff from a catchment depends on three things:

- The **size** of the catchment. Larger areas produce more runoff.
- The type of **surface** the rain falls on. Sand and grass absorb more water than does bare rock.
- The **intensity of the rain**. A light shower has a chance to sink into the ground. Heavy or continuous rains produce more runoff, especially late in the rainy season when the soil is already wet.

In theory, if no water is lost, 1 mm of rainfall should produce 1 litre of runoff water from every square metre of catchment. But the actual amount is never this much: some water will seep in, some evaporates, and some stays in the catchment.

The table below shows the percentage of the total rainfall that can be collected as runoff from various surfaces. These figures are approximate, as the actual amounts can vary considerably.

Percentage of runoff from various surfaces

Surface type	Annual rainfall		
	250–500 mm	**500–1000 mm**	**1000–1500 mm**
Corrugated iron sheet	85%	85%	85%
Rock	75%	75%	75%
Compacted soil	45%	50%	55%
Agricultural field	20%	30%	45%
Thatch roof	20%	20%	20%
Sparse grass	10%	**20%**	40%
Thick grass	10%	20%	35%

To estimate the amount of runoff from a catchment, you need to know the size of the catchment and the average amount of rainfall. Multiply by the percentage runoff given in the table.

Example

A farmer (the same one as in the box on the previous page) wants to set aside a 20 x 20 m (400 m^2) plot with sparse grass as a catchment. The average annual rainfall of the area is 600 mm. How much runoff water can be collected from this area?

Amount of water = annual rainfall x catchment area x percentage of runoff

= 600 mm x 400 m^2 x 20% (the figure in **bold** in the table above)

= 240,000 x 0.2

= **48,000 litres**,

or 48 m^3.

The catchment can supply about three-quarters of the family's annual needs of 63 m^3.

(heavier runoff means a bigger trap) and the amount of sediment it carries. If there is a lot of sediment, make a two-chamber trap – one chamber to catch sand, and a second one to trap finer silt. Add a filter mesh to trap leaves, twigs and other debris.

Dig the silt trap at least 3 m away from the storage tank. This is to prevent water from overflowing during heavy rains and damaging the tank.

Storage tanks

Water tanks can be built above or below the ground (see the box below). There are many different designs. They include:

Above ground

- Ferrocement tanks

Underground

- Hemispherical tanks
- Bottle-shaped tanks
- Dome-cap tanks
- Brick-cap tanks

Above or below the ground?

Above-ground tanks

Advantages

- These tanks are easy to inspect for cracks and leaks, and are easy to maintain and clean.
- Water can be taken out using a tap or pipe (gravity flow).
- The water is better quality (especially since above-ground tanks are often built to store water that comes from a tin roof).

Disadvantages

- Tanks take up space, usually near the house or kitchen.
- Tanks are expensive to build because the walls must be strong.
- Very wet weather or extreme heat may cause cracking.
- The water temperature varies more: warmer in hot weather, colder in cold weather.

Underground tanks

Advantages

- These tanks can store more water at lower cost because the ground supports the weight. This means walls can be thinner than for above-ground tanks.
- The water may come from the ground surface or from rooftops. The tank fills quickly.
- Underground tanks are cheaper than above-ground tanks.

Disadvantages

- Water must be removed with a hand-pump or bucket and pulley.
- It is difficult to empty the tank and to get inside to clean it.
- Leaks are hard to detect.
- The water may be contaminated by groundwater or flooding (select the site carefully).
- If the tank is left open, animals or small children may fall in and drown.
- The tank may be damaged by large tree roots or by groundwater.

How to select a site for a tank

Selecting a suitable site for the water tank is important, as it will be permanent! Do a preliminary study before designing and building the tank. If possible, compare two or more locations before selecting the most practical site.

Here are some important points to consider:

- Locate the tank where the largest amount of water can be stored with the least amount of digging or earth fill.
- If the tank is to be used for watering animals, build it near where the animals are kept.
- To keep the water from getting contaminated, choose a location where drainage from farmsteads, feedlots, sewage lines and similar areas cannot reach the tank.
- Avoid sites near unstable ground, such as gullies or landslides, or near deep-rooted trees. Do not plant trees with deep roots near the tank.
- Do not overlook the possibility of the tank suddenly collapsing and releasing water. Select a safe location for the tank, and put a solid foundation under it.

How to build and maintain a tank

Each tank design is different, so they are built in different ways. Here are some general guidelines:

- Line the inside of the tank to reduce the water losses through seepage. Appropriate low-cost lining materials include red clay, soil from termite mounds, cement, stone, bricks, or plastic.
- Cover the tank with a roof to reduce evaporation and to prevent mosquitoes from breeding. The cost of roofing can be minimized by selecting a design with a narrow opening at the top. If you do not plan to roof the tank, locate it at some distance from the house, and keep it free of vegetation.
- Check the tank regularly for cracks, and conduct routine maintenance. Do not allow the tank to stand dry for a long time. Always leave some water inside to prevent cracks.
- Clean the pipes and screens regularly to prevent them from getting blocked.
- Cover all inlets, outlets and overflow pipes with screens to prevent mosquitoes, other insects and rodents from getting in.

The following section describes five types of tanks. Use this information to assist local people to select the kind of tank that is best suited to their needs and conditions. It is *not* a detailed guide on how to build each type of tank. For this, consult a specialist.

Ferrocement tanks

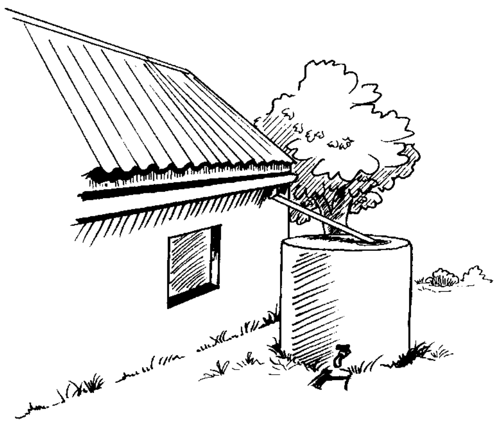
Ferrocement tanks are built above ground to store rainwater collected from rooftops. The walls and floors are reinforced with wire mesh. The walls do not need to be very thick, so little cement is needed. Paint the tank white to keep the water inside cool.

Advantages

- No excavation is required.
- It is easy to take water out of the tank through a tap.
- Leakage or damage can be detected easily.

Disadvantages

- Ferrocement tanks are fairly small: the biggest are 10 m^3 (10,000 litres).
- These tanks are relatively expensive.
- Skilled labour is needed to build them.



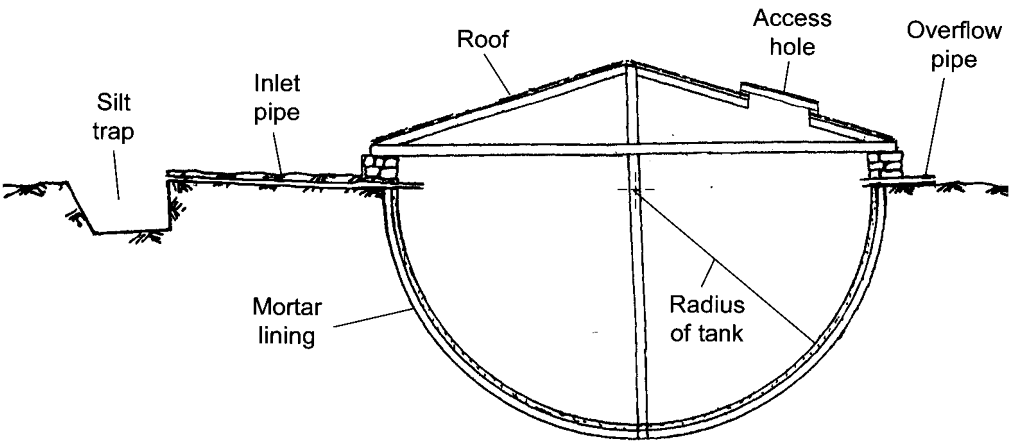
Ferrocement tank used to collect rainwater from a roof

Hemispherical tanks

Hemispherical tanks are shaped like half a football. They are built below the ground level. They store water collected from the ground surface or from rooftops.

Advantages

- Hemispherical tanks are fairly easy to make. This means that local people can build them.
- They cost less to build than other kinds of tanks.
- Drawing water and cleaning the inside is fairly easy, as these tanks are not as deep as other types.



Hemispherical tank

Disadvantages

- Hemispherical tanks take up a lot of space – which may be scarce around the homestead where tanks are most useful.
- A lot of water is lost through evaporation if the tank is not roofed properly.

Size and capacity of hemispherical tanks

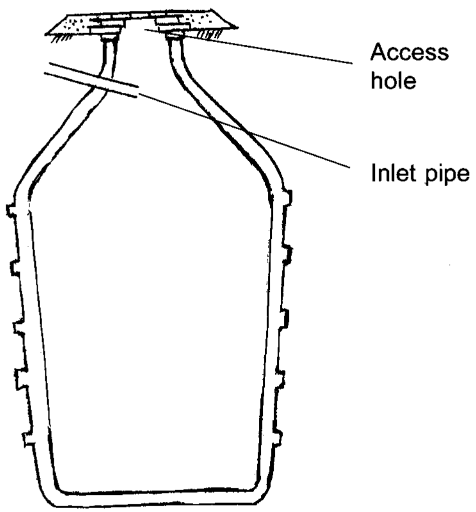
Radius or depth (m)	Volume (m^3)
3.5	89
3.2	68
3.0	56
2.6	36
2.5	32
2.1	19
2.0	16

Bottle-shaped tanks

Bottle-shaped tanks are built underground in the shape of a giant bottle. They can store runoff water collected from the ground surface or from rooftops. Water is removed with buckets or a handpump.

Advantages

- Bottle-shaped tanks are relatively cheap.
- They do not take up much space.
- If the catchment is protected, they can be used to supply clean water for household use.



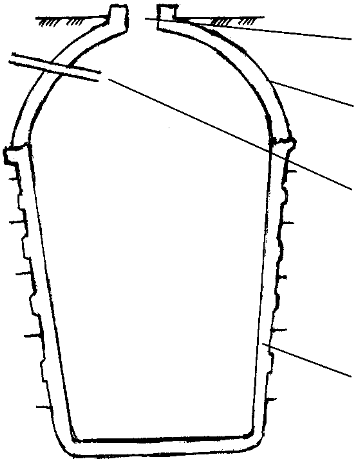
Cross-section of a bottle-shaped tank

Disadvantages

- Bottle-shaped tanks may collapse while they are being built, so they must be constructed by someone with experience.
- They are not suitable for clayey or sandy soils.
- Excavation work is difficult if the soil is very stony (dig a test pit to find out if this is the case).
- Bottle-shaped tanks are difficult to clean and maintain because of the small opening at the top.
- The tanks are difficult to drain completely.

Dome-cap tanks

A dome-cap tank is an underground tank built in two parts: a domed roof (or 'cap') made of reinforced cement, above a cylindrical pit lined with mortar. The dome may be above the ground, or it may be buried.



Cross-section of a dome-cap tank

Advantages

- Dome-cap tanks can be built in most soils types. They should not be built in clays or sandy soils that are more than 2 m deep.
- These tanks can last a very long time.
- They do not take up much space.

Disadvantages

- Dome-cap tanks are more expensive than hemispherical tanks.
- They can be difficult to build. Making the dome shape needs special skills.
- Cleaning and maintenance are difficult because of the small opening at the top.

Brick-cap tanks

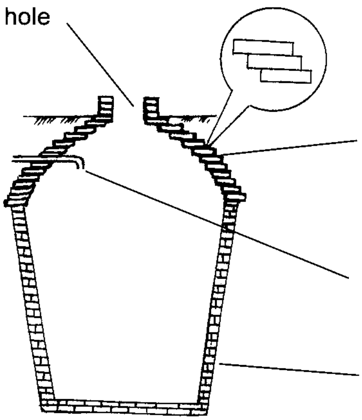
Brick-cap tanks are similar in shape to dome-cap tanks. The top is made of burnt bricks. Where bricks are made, they are a good, low-cost building material.

Advantages

- Brick-cap tanks are sturdy enough for relatively unstable sandy soils.
- They last a long time.

Disadvantages

- Bricks may be expensive and hard to find in rural areas.
- Laying the bricks requires a skilled mason.
- Cleaning and maintenance are difficult because of the small opening at the top.



Cross-section of a brick-cap tank

How much do tanks cost to build?

The cost of a tank depends on the tank's size and its design. The table below shows that the hemispherical and bottle-shaped tanks are the cheapest. But they have disadvantages: hemispherical tanks take up scarce land near the homestead, and the biggest bottle-shaped tanks hold only 30 m^3. The dome-cap tank needs less land and can be built in heavy clay soils.

The costs in the table below include the inlet pipe, outlet pipe and silt trap.

Cost of building water tanks per cubic metre of water stored (2003)

Tank type	Tank capacity (m^3)	Cost (birr) Materials	Labour	Total	Cost per m^3
Ferrocement tank	10	2571	412	2983	298
Hemispherical tank	30	1418	544	1962	65
	50	1730	748	2478	50
	60	1858	828	2686	45
Bottle-shaped tank	10	965	384	1349	135
	30	1299	656	1955	65
Dome cap tank	10	1602	498	2100	210
	30	2317	834	3151	105
	50	2860	1302	4164	83
	60	2964	1478	4442	74
Brick-cap tank	10	1474	428	1902	190
	30	2304	850	3154	105
	50	3072	1216	4288	86
	60	3400	1382	4782	80

100 birr = US$ 12.00

Irrigation

Erratic rainfall and water shortages are major constraints in Ethiopian agriculture. Irrigation can help overcome these problems.

Where to use irrigation

Agroclimatic zones Full or supplementary irrigation is necessary in most agroclimatic zones except the Wurch. At higher altitudes, the growing period is longer, and irrigation may not be worthwhile, except perhaps during drought and frost.

Soils All soils. Different irrigation methods are appropriate for different soil types.

Advantages of irrigation

- In dry areas and in the dry season, crop production is not possible without irrigation. In slightly wetter areas, growing crops without irrigation is possible, but supplementary irrigation helps guarantee a good yield.
- Irrigation increases the intensity of cropping, so raises the productivity of farmland. This helps reduce the pressure on eroded, fragile soils, so indirectly helps promote soil conservation and afforestation programmes.
- Water stored for irrigation can change the microclimate and bring additional economic benefits, such as fish production and water supplies for people and animals.

Disadvantages and constraints

- Irrigation is not possible everywhere: there may not be enough water available; slopes may be too steep, and soils may be unsuitable.
- If it is not managed properly, irrigation may pollute the groundwater with nitrates from fertilizers. Nearby wells used for drinking water may be contaminated.
- Over-irrigation, poor water management and leaky canals may cause waterlogging and drainage problems.
- Salt may build up in the soil.
- Mosquitoes can breed in stagnant water.
- Weeds may grow more quickly.

Siltation

The silt in rivers and irrigation water was once soil. Erosion in the catchment area or along canal banks produces silt, which irrigation water eventually brings into the farm.

Silt is normally seen as a bad thing. But it does have some advantages:

- It enriches the irrigated soil with plant nutrients.
- It improves the soil texture, increases permeability and increases the amount of moisture the soil can hold.

Here are the main disadvantages of silt:

- It reduces the amount of water that reservoirs can hold. If it is not removed, the soil may eventually fill the reservoir completely, making it useless.
- Silt deposited in canals and other irrigation structures increases the cost of maintenance. It clogs pipes and equipment such as pumps and sprinklers and makes them wear more quickly.

To reduce the damage caused by silt:

- Protect the catchment area with measures to conserve soil.
- Install filters and silt traps to protect important equipment.
- Design canals and other irrigation structures so they do not silt up.
- Regularly remove the silt from reservoirs and canals.

Salinity

Irrigation can make the soil salty, especially in dry areas. Crops grown on saline soil may grow stunted or may wilt, and produce low yields. Too much salt can ruin the land completely for cropping.

The salts can come from the irrigation water itself. Or they may already be deep in the soil. Irrigation water dissolves these salts, and they move upwards in the soil towards the surface through tiny pores called capillaries. When the soil dries out, the salts are left on or near the surface.

To reduce the risk of salinity:

- Every now and then, irrigate the field with more water than the crops need. The extra water will dissolve the salts. (This is called 'leaching'.) Drain away the excess water to remove the salts and to prevent waterlogging.
- Use irrigation water that is not salty.
- Use deep tillage and ridges to improve drainage (so the salts wash down out of the reach of roots, and to break up the cracks the salts use to move upwards).
- Plant hedges and trees to act as windbreaks and to reduce evaporation.

Irrigation methods

Irrigation water must be moved from where it is collected or stored to the field where it is used. In surface irrigation (flooding, basin and furrow), it can flow by gravity in open canals or closed conduits, or can be pumped through pipes. In most small-scale irrigation schemes, open earth channels are used. A lot of water may be lost through percolation and evaporation. Once it reaches the farm, field ditches carry the water to the irrigated fields. It may be necessary to install drainage systems to stop salts from building up in the soil.

Moving and lifting water

It may be necessary to lift water so it can be used for irrigation: if the fields are higher than the water source, or if the water comes from a well or underground tank. There are many ways of lifting water:

- Diesel or petrol engines.
- Wind power (windmills).
- Water power (e.g. hydraulic ram that use the force of the water flow to lift some up).
- Electricity, perhaps generated by solar panels.
- Animal power (often used in traditional irrigation systems).
- Hand or treadle pump (also used in traditional systems).
- Carried by people or animals.

Consider the following when choosing the type of lifting device:

- The height water has to be lifted.
- The distance to the water source.
- Farmers' experience in managing and maintaining the equipment.
- The availability of spare parts.
- The cost of buying and running the equipment.

In drip and pitcher irrigation, a pump and hose can be used to fill the buckets or containers, or the water must be carried by hand.

There are many different types of irrigation methods. The most suitable one depends on factors such as topography, the amount of water available, the crops and soil type.

This section describes six types of irrigation that smallholders in Ethiopia can use:

- Uncontrolled flooding
- Basin irrigation
- Furrow irrigation
- Drip irrigation
- Pitcher or clay-pot irrigation
- Bottle irrigation.

Uncontrolled flooding

This is the simplest form of irrigation. Water is led into the field and allowed to seep into the soil. Farmers use this method where there is more than enough water available.

Advantages

- Uncontrolled flooding is simple and easy to do.

Disadvantages and constraints

- Uncontrolled flooding can lead to over-irrigation and waterlogging.
- Water is applied unevenly over the field. Some places get too wet; others are too dry.
- This method is very wasteful in terms of water.

Uncontrolled flooding

Basin irrigation

Basins are flat plots of land surrounded by low earth ridges (dykes) or bunds.

Where to use basins

Slopes Slopes of up to 2.5% – or more when benched or terraced.
Soils Basin irrigation is used on all type of soils, but loamy soils are best. Coarse sands are not recommended. Use large basins on clay soils, and small basins on sandy soils.

Basin irrigation

Health impacts of irrigation

Irrigation schemes increase the risk of water-borne diseases such as bilharzia and malaria. Storage reservoirs, standing water in canals, and vegetation on the edges of ditches are breeding grounds for the snails that transmit bilharzia and the mosquitoes that carry malaria.

It is important to design and operate irrigation and drainage systems so as to minimize standing water. Even with these precautions, additional measures, such as the use of bednets with appropriate insecticides, can significantly reduce the threat of malaria in farming communities.

Consider using the following precautions:

- Do not locate storage reservoirs close to houses.
- Design canals and drains so they flow steadily (no stagnant water) but not too fast (no scouring or erosion).
- Keep debris and silt from accumulating in canals.
- Line canals to control seepage and waterlogging.
- Do not dig 'borrow pits' in canal banks as a source of soil or rocks for building or filling. Such pits can slow the flow of water or may get filled with stagnant water.
- Fill low spots in the irrigated field to eliminate standing water.

Crops Basins are good for growing rice and vegetables, and in orchards (where each tree stands in a small basin). They can be adapted for many types of crops, such as alfalfa, cereals, cotton, maize and groundnuts. For these, the basins must be the right size and shape, and water must be managed well.

Advantages of basin irrigation

- The farmer has good control over the irrigation water.
- The water can be used efficiently and applied uniformly over the field.
- Basins cost little to maintain.
- The basins help control erosion.
- Basin irrigation can use large streams as a water source.

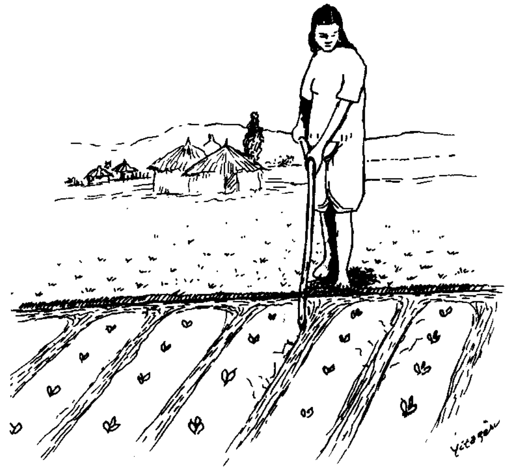
Disadvantages and constraints

- It is often necessary to move a lot of soil to make flat basins.
- Large flows of water are needed.
- The initial cost of making the basins and canals is relatively high.
- The dykes make it difficult to use equipment in the fields.
- Crops that are sensitive to flooding may not do well.

Furrow irrigation

Furrows are narrow ditches dug in the field between rows of crops. Water is led into the field from the irrigation channel through a gap in the bank of the channel, or through siphons (short, curved pipes that carry water over the bank). The water then flows through a series of furrows laid out at right angles to the slope.

Short furrows are best on sandy, porous, free-draining soils. Long furrows can be used on heavy clay and poorly draining soils.



Furrow irrigation

Where to use furrow irrigation

Slopes Furrow irrigation is well-suited to flat land or slopes gentler than 0.5%.
Soils It can be used on most soil types, but not coarse sands.
Crops It is suitable for row crops such as maize, sunflower, sugarcane and soybean, and for crops that are damaged by flooding, such as tomatoes, potatoes and beans. It is also used for horticultural crops such as vegetables, citrus and grapes.

Advantages of furrow irrigation

- Unlike basin irrigation, furrow irrigation does not need the plots to be level, so less earth has to be moved.
- Less water is needed than in than basin irrigation. Little water is wasted.
- All types of row crops that need well-drained and aerated soils can be grown.
- The farmer has good control over the irrigation water. Water can be applied uniformly.

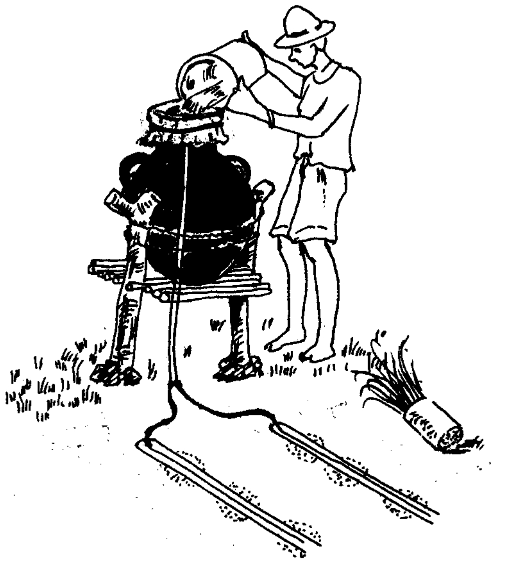
Disadvantages and constraints

- Furrow irrigation is labour intensive, especially on slopes.
- The furrows and ridges must be continuously reshaped.
- The farmer must be on the spot to control the distribution of water in the furrows.

Drip irrigation

Drip irrigation uses small amounts of water to wet the soil just where plants need it. It does this by using special low-pressure pipes with holes (called 'emitters') in them, so the water drips out into the soil near the plant roots. The farmer puts water into a large bucket or tank connected to the pipes. A filter at the bottom of the tank prevents silt from getting into the pipes and clogging the holes.

Drip irrigation systems can be very small scale, for example using plastic buckets and hoses to water a vegetable garden. Or they can be larger scale, covering several hectares.



A low-cost drip irrigation 'bucket kit' needs only 20–40 litres per day to water a 30 m² vegetable plot. To avoid making a hole in the bottom of the clay pot, this farmer is siphoning the water out from the top into the drip hoses.

Where to use drip irrigation

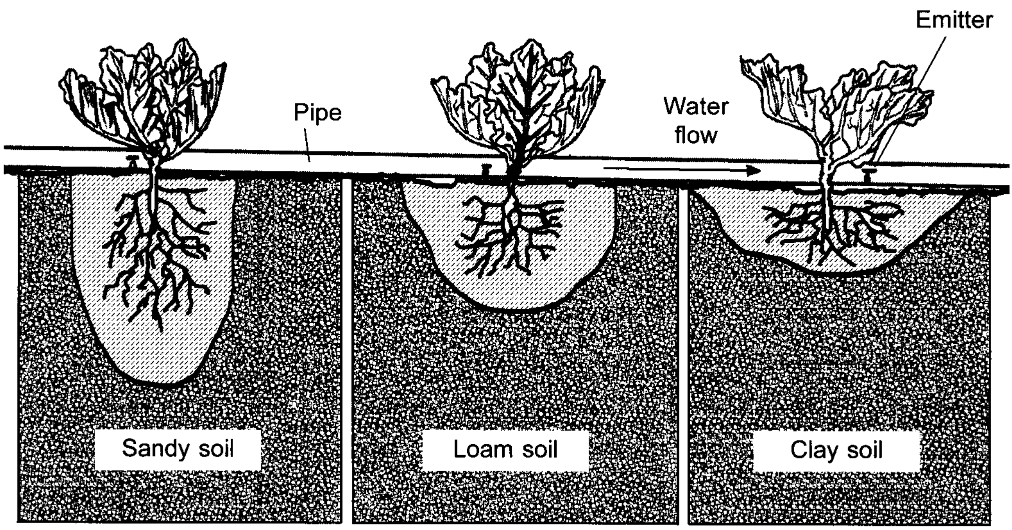
Slopes Drip irrigation can be used on sloping or undulating land.

Soils Drip irrigation can be used on any kind of soil. On light textured soils, the holes in the pipes must be spaced closer together (every 10–15 cm) than on heavy soils (20–30 cm).

Crops Drip irrigation is useful for small areas and high-value crops, such as vegetables.

Advantages of drip irrigation

- Drip systems are very efficient. They use very little water, and evaporation and percolation losses are low. Most of the water is used by the crop.
- Crops can be grown in the dry season, and may fetch a better price as a result.



Soil wetting under drip irrigation on different soils

- Water of marginal quality (even pond water) can be used, as the filter in the bucket keeps silt out of the pipes.
- Once the system is set up, drip irrigation takes little time or work.
- Farmers can decide when to water the crops.
- Soluble fertilizer (such as animal or human urine) can be mixed with the water in the bucket.

Disadvantages and constraints

- The buckets, filters and pipes have a high initial cost (except for very small-scale systems).
- Skilled labour is needed to operate and maintain the equipment.
- For large drip-irrigation systems (covering many hectares), efficient organization and management are needed.
- Dissolved minerals or mould may clog the pipes, holes and filters, shortening the useful life of the system.
- Care is needed when cultivating to avoid damaging the pipes.

Pitcher or clay pot irrigation

Pitcher irrigation uses porous clay pots that are buried up to their necks in the ground. Water is poured into the pots and kept at a depth of 20–30 cm. The pots can hold 5, 10, 15 or even 20 litres. The size and shape of the pots depends on the type of crop. Small, round pots can be used for growing vegetables. Larger, deeper pots can be used in orchards. The pots have lids to stop the water inside from evaporating.

Where to use pitcher irrigation

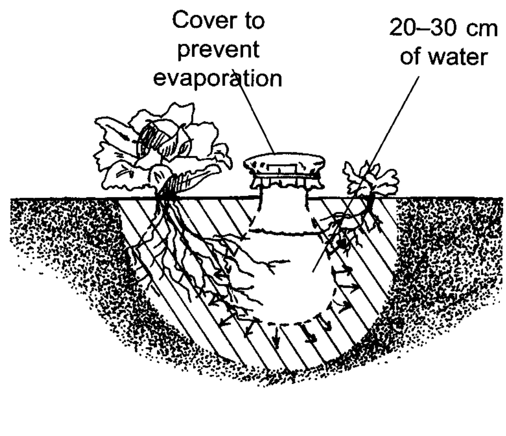
Slopes All.

Soils All.

Crops Pitcher irrigation is useful for small areas, such as vegetable gardens and orchards.

Advantages of pitcher irrigation

- Farmers do not have to water their plants every day. The pots need to be filled only once a week or every two weeks.
- Very little water is needed, and little is wasted.
- There is little danger of making the soil saline (a common problem with



Pitcher irrigation for shallow-rooted plants. Water seeps through the porous pot and wets soil

7

Managing livestock and fodder

Livestock use plants, and parts of plants, that people cannot eat, and they convert it into meat, milk and hides. They also provide labour for ploughing, and dung that can be used as fertilizer. While animals can cause erosion, various methods can limit this and improve the efficiency of resource use.

There are two main ways to feed livestock:

- **Grazing and browsing** The animals are let out to graze on pastures and browse on shrubs. The herder moves the animals from place to place, prevents them from straying (by herding or with fences), and protects them from predators and thieves. The quality of the grazing can be conserved or improved in various ways.
  This chapter describes various ways of managing pasture, by improving the mix of forage species, conserving and improving the soil fertility, and by managing livestock.
- **Cut-and-carry** Under cut-and-carry, the animals are kept in a shed or paddock, and the farmer harvests the feed and takes it to them. The feed can be freshly cut, or fed as hay or silage. The farmer can also buy feed supplements. This management approach is also called 'zero grazing' or 'stall feeding'. It is best used with animals with high production levels.
  This chapter also describes the components of cut-and-carry. It covers how to house and feed livestock, and how to conserve feed as hay and silage.

Animals can be fed with a combination of grazing and cut-and-carry. For example, they may be allowed to graze, but be given supplementary feed in the form of hay or concentrates. Or they may be fed by cut-and-carry during the wet season when forage is abundant (and crops are growing in the fields), and allowed to graze on permanent pastures and crop residues in the dry season.

Gathering enough feed for livestock is hard work. To save the work of carrying fodder long distances, the farmer can tether the animals near the fodder source and feed them there.

Over-sowing

'Over-sowing' means broadcasting seeds of good-quality pasture plants on existing natural grazing land. It is not necessary to cultivate the land or apply fertilizer (though this can help). This is the cheapest way to improve pasture.

Over-sowing improves the quantity and quality of feed. In the first year, it can yield the equivalent of an extra 500 kg of dry hay per hectare. It can produce even more in following years if the grazing area is managed well.

Where to use over-sowing

Agroclimatic zones All moist and wet zones where grazing land has been degraded.

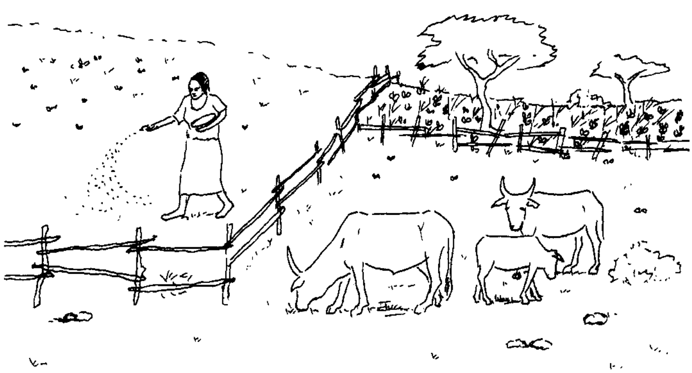
Soils All, especially lighter and looser soils, in overgrazed areas.

Advantages of over-sowing

- Over-sowing improves the quantity and quality of forage.
- Sowing legumes improves the soil fertility.
- Sowing on degraded soils reduces erosion.
- The seed is cheap, and only a little is needed.
- Little labour is needed.

Disadvantages and constraints

- Forage seeds may not be available easily.
- Over-sowing on communal grazing land must be organized by a group.



Pastures can be improved in various ways, including oversowing with forage seeds, stock exclusion and fertilizer application

Forage species for over-sowing

Legumes	Grasses	Fodder trees
Alfalfa	Buffel grass	Leucaena
Axillaris	Cocksfoot	Sesbania
Greenleaf and silverleaf desmodium	*Panicum*	Tree lucerne
Seca and verano stylo	*Phalaris*	
Siratro	Rhodes grass	
White clover	*Setaria*	

See page 228 and Chapter 9 for more information on forage species.

How to broadcast seed

Over-sow pasture before or at the beginning of the rainy season.

1 Choose a site with loose soil, and select seeds that will grow well in your area (see the lists of forages on page 228 and in Chapter 9).
2 Treat seeds that have hard coats (see the box below).
3 Apply 0.5–1.0 kg of seed per hectare, depending on the type of plant. Only a little seed is needed, so mix it with dry soil or sand to make sowing easier.

Management

Keep animals off the area while the pasture is growing.

Over-sowing is usually done on grazing land that the community controls. The community should form a management group to decide:

- When and how to use the forage (cut-and-carry or grazing).
- The type and number of animals to feed or graze.
- How to keep animals off the pasture.

Treating seeds with hard coats

Some legume seeds take a long time to germinate because they have hard coats. Here are four ways to treat them to make them germinate faster.

- Rub small quantities of seed on an **rough surface**, such as concrete or sandpaper. This is the most common method used by small-scale farmers.
- Put the seed, along with some gravel, in a **cement mixer** and run the mixer for at least 30 minutes. This method is useful when there is building going on nearby.
- Run the seed through a **hammer mill**.
- **Hot water treatment:**
  1 Boil water in a pot, then remove the pot from the fire and put the seeds into it.
  2 Soak the seeds for 5–10 minutes.
  3 Spread the seeds out in a thin layer (less than 1 cm thick) so they cool quickly.
  4 Plant the seeds.

Under-sowing

'Under-sowing' means sowing forage seeds (usually legumes) in a field where other crops are already growing:

- In a field of annual crops, so the forage can be used after the annual crops have been harvested.
- In a plantation of permanent crops, such as coffee or enset.

The forage can be grazed, or it can be cut and fed to livestock.

Where to use under-sowing

Agroclimatic zones All zones except Alpine Wurch and Dry Bereha. Not suitable for pastoral areas.

Soils Wide range of soils used for cropping.

Advantages of under-sowing

- Under-sowing produces additional animal feed from land that is already used.
- It improves the feeding value of crop stubble.
- Under-sowing with legumes improves the soil fertility.

Disadvantages and constraints

- If cut-and-carry is used, extra work is needed to harvest the forage.

How to do under-sowing

1 Sow the forage seed when weeding the main crop for the last time. Use a low seeding rate (12–15 kg of seed per hectare, or 80–100 g/100 m row).

2 Wait until after harvesting the annual crop and when the forage crop has grown. Then allow the animals to graze the field, or cut the forage and use it as feed.

Types of forage to sow under annual and permanent crops

	Sow under annual crops (maize, sorghum, etc.)	**Sow under permanent crops** (coffee, chat, enset, etc.)
Forage species	Vetch Lablab Cowpeas	Axillaris Greenleaf or silverleaf desmodium Siratro Verano stylo

See page 228 and Chapter 9 for more information on forage species.

Forage species for livestock exclusion areas

Herbaceous legumes	Grasses	Tree legumes
Alfalfa	Buffel grass	Leucaena
Axillaris	Guinea grass	Sesbania
Caribbean and shrubby stylo	*Panicum maximum*	Tree lucerne
Common vetch	*Phalaris*	
Greenleaf and silverleaf desmodium	Rhodes grass	
Lablab	*Setaria*	
Siratro		
White clover		

See page 228 and Chapter 9 for more information on forage species.

3 Sow the seed before or at the beginning of the rains. Use a low to medium (2–3 kg/ha) seeding rate, or a 'finger pinch' of seed per microcatchment. If the soil has not been disturbed, sow the seed on relatively loose surfaces.

Management

Forage produced in stock exclusion areas should be cut and taken to the animals for feeding. Do not reopen these areas for grazing.

The community group that manages these areas must ensure that livestock are kept away, and that the forage is distributed fairly.

Stock exclusion areas in Tigray

In the 1990s, the farming community in Tigray decided to improve the degraded lands in the region. They formed a committee to design how to do this. The committee decided to form livestock exclusion areas.

The vegetation cover in these protected areas has improved, allowing much degraded land to be reclaimed for forage production.

The committee is responsible for keeping the animals out of the exclusion areas. It also organizes the harvesting and distribution of the forage.

Fodder banks

Fodder banks are reserve pastures that are used to feed livestock during the dry season. A mixture of improved grasses and forage legumes provides the best quantity and quality of feed. Acacia and other native trees can also provide forage. Animals should be kept off the fodder bank during the growing period.

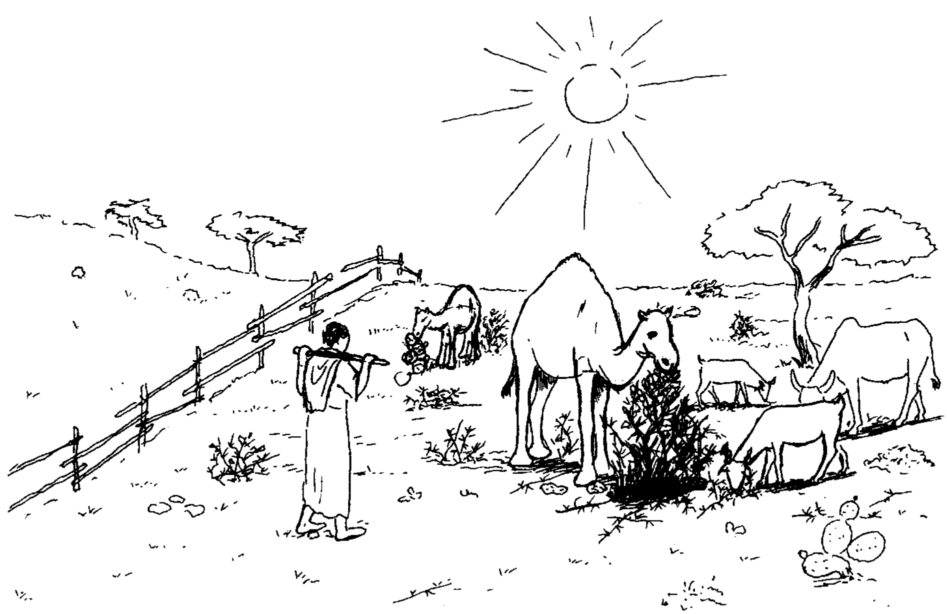
Where to use fodder banks

Fodder banks are especially useful in pastoral areas where feed shortages during the dry season are a serious problem. They can also be used in highland areas.

Agroclimatic zones All zones except Alpine Wurch and Dry Bereha.
Soils Wide range of soils.

Advantages of fodder banks

- Fodder banks ensure that there is feed available all year round.
- No additional labour is needed since the feed is conserved in the field.
- Milking cows do not need to travel in search of feed during dry season. This improves animal production and productivity.
- Improved forage types can yield large amounts of feed.



A fodder bank is grazing land set aside for use when pasture is scarce

Disadvantages and constraints

A grazing-land-use committee or pastoral association must decide how to manage the fodder bank. It may be difficult to organize such a group and help them agree on what to do.

How to make a fodder bank

1 Help organize a grazing land users' committee or pastoral association to manage the fodder bank.
2 This group sets aside an area of rangeland to use as the fodder bank. It also decides how to manage the bank.
3 Choose which types of forage to sow in the fodder bank.
4 Plant or sow the seeds at the beginning of the rains.
5 Keep the animals off the pasture until it is well established.

Forage species for fodder banks

Succulents	**Legumes**
Atriplex nummularia (Oldman saltbrush)	Leucaena
Opuntia ficus-indica (Spineless cactus)	*Stylosanthes hamata* (verano)

See page 228 and Chapter 9 for more information on forage species.

Controlled burning

Pastoralists burn rangeland to improve the amount and type of feed it produces. Fire is a cheap way to turn bush into more valuable pasture with palatable grasses and other types of forage. Animals can graze lightly on the cleared areas. Burning can also be used in the highlands to clear unpalatable grasses from degraded grazing land.

Where to use controlled burning

Agroclimatic zones All except Alpine Wurch and Wurch.
Soils All.

Advantages of controlled burning

- Fire removes unpalatable, mature plants and thick bush.
- Burning helps control ticks.
- The range is burned just before the short rains, allowing the pasture to regrow vigorously after the rains.
- Over-sowing with improved forage types after the fire improves the grazing.

Disadvantages and constraints

- Burning the bush may disturb wildlife.
- Fires may burn out of control if they are not managed properly.
- Additional labour is needed to control the fire.
- Some plant and animal species may disappear, threatening biodiversity.

How to burn the bush

1 At the beginning of the short rains, decide what area is to be burned.
2 Prepare firebreaks to control the burning. Try to burn immediately after a rainshower to minimize the risk of the fire spreading
3 Watch the fire and prevent it from spreading to the wrong areas.
4 Once the fire is out, if possible sow seeds of suitable forage species (see *Over-sowing*, page 186).

Clearing bush by hand

Clearing bush by hand takes a long time, and is hard work. But it may be necessary to clear small areas of bush by hand:

- To allow animals to pass through a dense piece of bush.
- To clear land where there is not enough grass for it to burn easily.
- To make firebreaks before controlled burning.

Permanent grass–legume pasture

Permanent grass–legume pastures are sown on prepared seedbeds (unlike over-sowing, where the seedbed is not prepared). These pastures are used mainly for controlled grazing in dairy farms and other intensive, large-scale farms (see page 197).

Where to use grass–legume pastures

Agroclimatic zones All Dega and Weyna-Dega, Moist and Wet Kolla, and Moist Bereha.

Soils Well-drained, fertile soils.

Advantages of grass–legume pastures

- The pasture produces large amounts of high-quality forage.
- The pasture protects the soil from erosion.
- The legumes maintain or improve soil fertility.
- If it is managed properly, the pasture can last for years.
- The pasture can be used to produce seeds of pasture species.

Disadvantages and constraints

- Both fertilizer and forage seed are expensive.
- Managing the pasture needs skilled labour.
- Weeds must be controlled.

How to grow the pasture

You will need seeds of improved forage types, fertilizer, and equipment to prepare the seedbed.

1 At the beginning of the rains, prepare a clean, fine, firm seedbed, like that for cereals.
2 Sow the seeds at a rate of 6–10 kg/ha. Cover them lightly.
3 Allow the pasture to grow before allow animals on it to graze.
4 After the pasture is established, do not allow livestock to graze it lower than 10–15 cm high in the Dega and Weyna-Dega zones (20–30 cm high (in Kolla zones).

5 Keep the animals out of the pasture to allow the plants to produce seed and reproduce. This is especially important for legumes.
6 Control weeds.
7 Maintain a balance between grasses and legumes by reseeding if necessary (see *Over-sowing*, page 186).

Forage species for permanent pasture

Dega	**Weyna-Dega**	**Wet and Moist Kolla**
Cocksfoot	Alfalfa	Buffel grass
Phalaris	Axillaris	Desmodium
Tall fescue	Desmodium	Green panic
Clover	Phalaris	Rhodes grass
	Rhodes grass	Siratro
	Setaria	Stylo
	Siratro	
	Clover	
	Verano and seca stylo	

See page 228 and Chapter 9 for more information on forage species.

Controlled grazing

Controlling the number and type of livestock that graze a pasture prevents overgrazing and avoids wasting feed. The animals will grow better and produce more meat and milk.

Cattle are grazers and goats are browsers, so they eat different types of plants. Together, they use the pasture more fully than a herd of cattle or goats would alone.

Where to use controlled grazing

Agroclimatic zones All zones except Alpine Wurch.
Soils All.

Advantages of controlled grazing

- Controlled grazing allows the forage to grow continuously, and produces enough fodder throughout the year.
- It maintains a good mix of plant types in the pasture.
- It maximizes animal production from a pasture at minimal cost, and over a long time.

Disadvantages and constraints

A grazing-land-use committee or pastoral association must decide how to manage the pasture. Organizing such a group and helping them make decisions may be difficult.

How to manage controlled grazing

- Allow milking animals and young animals to graze a pasture first, so they get the best forage.
- Allow different types of animals (cattle, sheep and goats) to graze. This makes the best use of a mixed pasture.
- Keep the grazing animals on the pasture for a maximum number of hours each day.
- Stop the grazing when the plants are forming seed. This allows them to regrow the next year, even if they are grazed heavily after seeding.
- Maintain a long-term balance between the grasses and legumes in the pasture. Stop the grazing, clear bush and weeds (see *Controlled burning*, page 194), and reseed the pasture if necessary (see *Over-sowing*, page 186).

Rotational grazing

Rotational grazing is a form of controlled grazing. It involves dividing pastureland into several paddocks, and allowing livestock to graze each in turn. The animals graze for a certain time (for example, one week) before moving to the next paddock. The grass in the newly grazed paddock has a chance to regrow until there is enough forage to it to be grazed again. The number of cattle has to be adjusted to the amount of grass available, especially during the dry season. This form of rotational grazing is used in ranches and commercial farms.

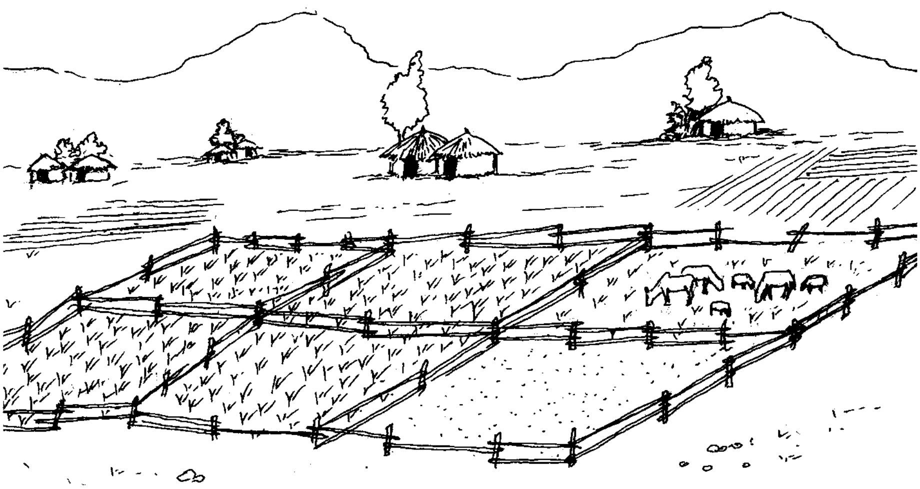
Where to use rotational grazing

Agroclimatic zones Moist and Wet Wurch; all Dega, Weyna-Dega and Kolla.
Soils All.

Rotational grazing is possible where there are private grazing areas and where animals graze between cropped areas. Where grazing land is communal and different types of livestock graze together, it may not be practical.

Advantages of rotational grazing

- Rotational grazing allows pastureland to be used efficiently. Animals are regularly let onto fresh pasture, which they can graze fully before being allowed into the next area.



Rotational grazing allows the pasture to recover before it is grazed again.

- It minimizes the incidence of livestock diseases by breaking the life cycles of parasites.
- It ensures that there is a supply of quality feed available all year round.

Disadvantages and constraints

Extra work is needed to maintain the paddocks and to make sure the animals stay in the right one.

How to manage rotational grazing

1 Fence off the required number of paddocks using fences, stones or lines of fodder trees. Decide the order in which the animals will graze. Then allow them into the first paddock.
2 Let the animals to graze each paddock properly before letting them into the next one.

Rotational grazing by pastoralists

Pastoralists use an extensive form of rotational grazing: they use different grazing land during the wet and dry seasons. In the wet season, they graze rangelands that have temporary sources of water. When these water sources dry up, they move their herds to dry-season pastures with permanent wells.

This strategy avoids overusing the grazing resources. However, if the pattern is interrupted – for example by insecurity – the pastoralists may be forced to use their dry-season pastures too soon. In this case, there may well be too little grazing later in the year.

Cut-and-carry

Cut-and-carry involves keeping animals in a shed or paddock, and bringing fodder to them – rather than allowing them to graze outside. It is also called 'zero grazing' or 'stall-feeding'. It is particularly useful for high-value livestock such as dairy cattle and goats, fattening animals, and young animals raised for slaughter. It uses the land in an intensive way, so is often used where land is scarce. It requires a dependable source of quality feed, sufficient labour to collect the feed and carry water, and a reliable market for the products.

Where to use cut-and-carry

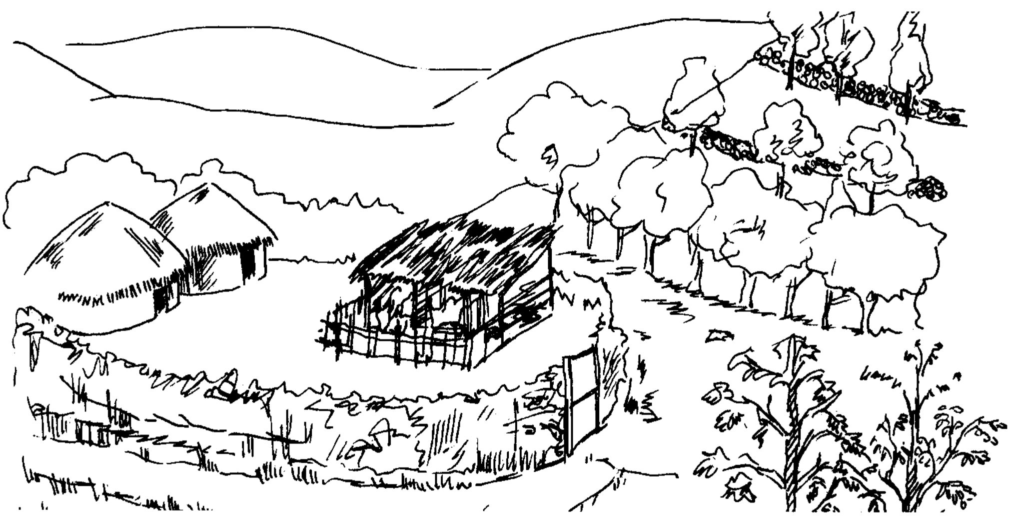
Agroclimatic zones All Wurch, Dega and Weyna-Dega; Moist and Wet Kolla.
Soils All.

Wet and dry season options

In the wet season, you can cut fresh forage and feed it to livestock. On irrigated land, you can produce green forage that can be cut frequently to supply feed throughout the year.

Feed is generally scarce in the dry season. Options include:

- Allow the animals out occasionally to graze on pasture and crop stubble. However, the grazing available may be of low quality, and the animals may compact the soil.



Managing feed properly is easy if the livestock are confined in a shed

- Grow extra forage so you can conserve it as hay or silage, then store it and feed it to the animals during the dry season.
- Use crop residues (such as straw) as feed. You can store them, and treat them with molasses or urea to make them more palatable and improve their quality.
- Match the number of animals with the amount of feed available.

Advantages of cut-and-carry

Cut-and-carry has several advantages over grazing:

- The animals do not spend energy searching for grazing, and they can be kept out of the sun.
- Farmers can ensure that their animals get good-quality feed, and less feed is wasted.
- An area of land can produce more total feed because a stand of forage can be harvested repeatedly.
- The animals put on weight faster and produce more milk. They suffer less from diseases and parasites.
- The animals do not overgraze pastures, trample fragile soils or cause erosion.
- The dung and urine can be collected and used as manure or for other uses.

Disadvantages and constraints

- Enough feed may not be available to feed the animals. (Match the number of animals to the amount of feed available.)
- Feed may be wasted when it is being transported or stored. Cutting too much feed at one time is also wasteful. (Cut only what is needed each day.)
- Feeding unwilted legumes can cause bloat. (Leave legumes for several hours to wilt before feeding them. Mix grasses and legumes in the feed.)
- Cutting feed too early in the season reduces the quantity of the forage. (Cut forage when the yield is optimal and the quality is high.)
- Cut-and-carry requires a lot of labour – to collect the forage and feed it to the animals, to fetch water, to keep the shed clean, and to transport manure. (Match the number of animals to the labour available.)
- Cut-and-carry requires more investment than grazing.

Cut-and-carry, or grazing?

Should animals be fed by cut-and-carry, or should they be allowed out to graze? Here are four factors to consider:

- The amount and type of land available.
- The distance to the source of water.
- The amount of labour available.
- Farmers' knowledge and awareness of the cut-and-carry system.

How much land is available, and what type is it?

You will need some land where you can grow feed for the animals. Cut-and-carry requires less land than grazing, but the land must be reasonably fertile so you can grow large amounts of feed. It may be possible to improve the quality of the soil by using fertilizer or manure, and by harvesting and conserving water. You can also grow feed on conservation bunds and other structures, in alley cropping, roadsides and other unused land.

If you can collect or grow enough feed, then cut-and-carry is an option. Otherwise, the animals must be allowed to graze all or some of the time, or fed with hay or silage.

If the land is severely degraded, livestock should be kept off it. Cut-and-carry may be the only option in such cases.

How far away is the water source?

Fetching water is a major chore, and it is too much work to fetch water by hand for more than a few animals. Water sources include wells, storage tanks, reservoirs and streams. See pages 160–175 for ways to collect water and make it available to livestock.

- If the water source very close by, the animals can be kept in the shed or enclosure all the time.
- If the water source is reasonably close (less than 2.5 km, or a half-hour walk), the animals can be fed by cut-and-carry. Lead them to the water source twice a day so they can drink.
- If the water source is further away than this, cut-and-carry is impractical. Allow the animals to graze, but consider giving them supplementary fodder.

How much labour is available?

Cut-and-carry requires labour to grow high-quality forage, feed and water the animals, and to handle manure. Depending on the number of animals, this generally takes several hours a day. This work often falls to the women.

Animals that are left to graze must be tethered or kept in a fenced area so they do not stray. If they are herded on open land, someone must look after them. One or two people can look after a whole herd.

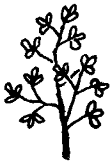
Do farmers know about cut-and-carry?

Farmers who are used to grazing livestock may be reluctant to switch to cut-and-carry. It requires a different set of skills (to grow forage, for example), and even a different lifestyle. Farmers may need to be convinced of the benefits, and they may need to learn these new skills.

Types of forage

Grasses

Elephant grass, Guinea grass, *Phalaris*, Rhodes grass and *Setaria*.



Herbaceous legumes

Alfalfa, cowpea, clover, desmodium and vetch.

Crop residues

Straw, stover and the stalks, leaves and pods of pulses.

Forage from trees and shrubs

Tree legumes such as *Leucaena*, *Sesbania* and tree lucerne, and other trees and shrubs.

Other crops

Enset, fodder beet and sweet potato vines.

Sources of feed for cut-and-carry

Feed may come from the following sources:

- **Naturally growing vegetation** Trees, shrubs, grasses and other vegetation (including grasses cut from roadsides, hedgerows and other waste land, and weeds removed from fields).
- **Planted forage** This includes fodder grasses, legumes, trees and shrubs grown in alley cropping and fields, and planted on bunds and terrace risers, grass strips and other conservation structures. Planted forage is often used to make hay or silage.
- **Crop residues** Cereal straw (tef, oats, barley), stover (maize, sorghum, millet) and pulse residues (horsebean, lentils, peas, etc.). In some parts of Ethiopia, crop residues form more than 60% of the livestock feed.
- **Agro-industrial by-products** These include milling by-products, molasses, brewer's grain and oilseed cakes.

Planting forage

Forage crops can be planted in various locations:

- On a plot of land near the animal shed.
- On bunds, terrace walls and other soil-conservation structures (see Chapter 5).
- As intercrops with food crops (see *Multiple cropping*, page 82, and *Under-sowing*, page 188).
- In shelterbelts and live fences.
- On degraded land or other areas unsuitable for crops or pasture.

Forage crops can be planted in mixed stands. For example, a plot may be planted with perennial grasses and legumes. A mixture of tree legumes and grasses may be grown in a hedge or on a terrace wall.

If grasses are grown near cropland, cut them often enough so they do not produce seeds and become weeds.

Plots close to the house can produce large amounts of forage because the soil is usually fertile and the family can give a lot of attention to the crop.

Farm sites for different forage types

	Trees and shrubs	Herbaceous legumes	Grasses	Root crops
Backyard forage plots	Leucaena Pigeonpea Sesbania Tree lucerne Calliandra *Ehretia cymosa* *Terminalia*	Alfalfa Cowpea Green and silverleaf desmodium Lablab White clover	Buffel grass Elephant grass Guinea grass Oats Phalaris Rhodes grass	Enset Fodder beet Sweet potato
Bunds, terraces, contour strips	Leucaena Pigeonpea Sesbania Tree lucerne Calliandra *Ehretia cymosa* *Terminalia*	Lablab Green and silverleaf desmodium Alfalfa Verano Vetch White clover	Guinea grass Gatton panic Phalaris Rhodes grass Setaria	
Hedges, shelterbelts	Leucaena Pigeonpea Sesbania Tree lucerne Calliandra *Ehretia cymosa* *Terminalia*	Climbing legumes such as lablab	Elephant grass	

See page 228 and Chapter 9 for more information on forage species.

For high-yielding dairy cattle, consider irrigating the forage plot to increase the amount of feed produced. Good soil fertility is important for high yields. Consider using organic or inorganic fertilizers to improve the soil fertility.

Keep livestock out of forage plots. Cut the forage and carry it to the animals.

Forage from trees and shrubs

Leaves and small branches from trees and shrubs are a useful source of fodder. They may grow naturally, be planted for other purposes (such as to stabilize bunds), or planted deliberately for forage. Forage trees can also produce fuelwood and construction poles, and can be used for beekeeping. Farmers also like the shelter and privacy provided by trees around the house.

See Chapter 8 for how to plant forage trees.

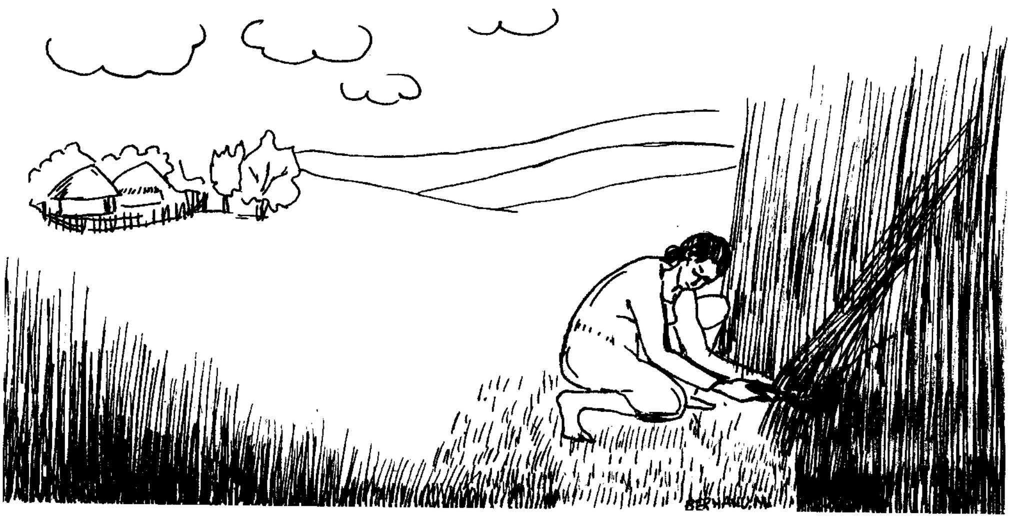
For a hedge of tree legumes, space the trees 0.5 m apart in a double row. One kilometre of forage hedgerow can produce up to 5 tonnes of fresh fodder (or 1.7 tonnes of hay) a year.

Both leucaena and gliricidia can be harvested every 2–3 months, depending on the moisture availability and the soil fertility. Leucaena can be harvested when it reaches 1.5–2 m high. Do not allow forage trees to grow more than 2 m high. Leave at least 25% of the branches so they can regrow.

This type of forage is high in proteins and minerals, but feeding too much can cause problems. Tree legumes such as leucaena should not form more than 30% of the total feed. Mix them with grasses and other types of feed.

Harvesting forage

1 When to cut the forage, and how much to cut, depends on the forage species. Make sure the crop can regrow so it can be harvested repeatedly. For example elephant grass can be cut at a height of about 20–30 cm when it is 90–120 cm high. It can be allowed to regrow and harvested repeatedly about once a month.
2 Harvest the forage according to a pattern. Start at one end of the row, and cut enough forage for the animals for that day. The next day, cut the next plants in the row. Carry on until you reach the end of the row, then begin again at the other end. This means you will always have enough forage available.
3 Cut only the amount needed each day. Green forage should not be stored because it will rot and animals will refuse to eat it.
4 Allow the cut forage to wilt for a few hours to lower its moisture content. This will reduce the content of toxic substances and help avoid the risk of bloat when feeding leguminous forage.
5 Tie it in bundles (or put it in baskets) and carry it to the livestock shed.



Cut forage according to a pattern, to allow the plants to regrow before you harvest them again.

Feeding forage

1 Chop the forage up to increase intake and reduce wastage.
2 Put the forage in feeding troughs (rather than on the ground) to reduce wastage. If possible, feed the animals individually to make sure each gets enough feed. Give extra forage to high-yielding milk animals and to young animals.
3 If animals do not eat some of the feed, use it as manure or to make compost.
4 Plan to conserve and store enough feed (in the form of hay, silage, crop residues and concentrate) to last throughout the year.

Livestock housing

A shed provides shelter from the sun and rain, protection from predators and thieves, and somewhere to store feed and care for young and milking animals.

How to build livestock housing

Build a livestock shed on a slight slope (so water drains away), close to the farmhouse so it is easy to supervise the animals. If possible, make a gently sloping concrete floor, that allows manure, urine and waste water to drain away into a gutter and from there into a pit, where it can be collected and used as fertilizer. Line the gutter and pit with clay or concrete so the waste water does not seep into the ground.

The size of the shed depends on the type and number of animals. An adult cow needs about 3 m^2 of space. A goat or sheep needs about 0.8 m^2.

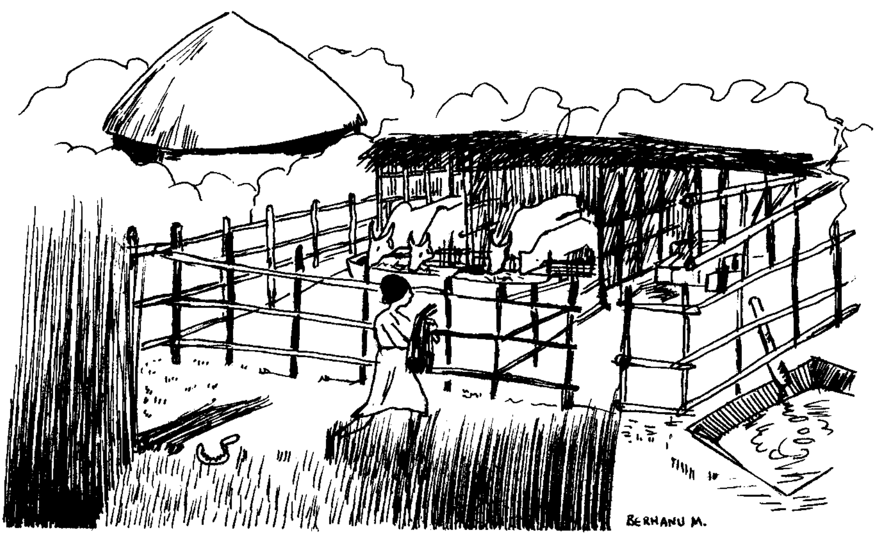
Make separate pens inside the shed for each individual animal, or for several animals of the same type. Keep males away from females (so you can control mating), and keep milking cows separately from calves and heifers.

Make a roof over the shed to protect the animals from the sun and rain. Make walls (or plant a shelterbelt) to protect them from the wind.

Plant a forage plot close to the shed so it is easy to cut and carry feed to the animals. Set aside some space in a dry place to store feed.

Put feeders down one side of the shed, and put a mineral block in each pen so animals can lick it.

Sheep and goats can be kept in a pen with a raised, slatted floor. The dung falls through the slats and can be collected from beneath the pen.



Livestock feed

Feeding is the most important aspect of livestock production. Animals that are well-fed grow and mature quickly (so can be bred or sold earlier), produce a lot of milk, can work hard, and do not fall ill easily. Female animals will come into heat sooner after giving birth, so can be bred again more quickly. It is important to give animals enough feed of sufficient quality, as well as enough water.

Feed components

The main components of the diet of cattle, sheep, goats, horses and camels are:

- **Roughage** Grasses, legumes, tree leaves, crop residues, hay and silage. These feeds contain a lot of fibre and should form over 2/3 of the feed.
- **Concentrates** Cereal seeds, wheat bran, molasses, *atela* (slurry from local brew) oilcake and meal, skim milk and whey. These feeds are high in energy and protein. They should not form more than 1/3 of the feed.
- **Mineral supplements** Roughage and concentrates usually contain most of the minerals animals need. However, it may be necessary to add minerals if the feed is deficient. Minerals are especially important for dairy animals and for young animals. Local sources of minerals include *amole* (a type of salt block), *bole* (a mineral soil) and *hora* (salty lake water).
- **Water** Animals get some of their water needs from fresh forage. They also need drinking water (see page 217).

Moisture contents vary, so...

1 kg of **hay** (16% moisture) contains the same amount of roughage as...

4.2 kg of freshly cut **elephant grass** (80% moisture)

or

1.7–2.1 kg of **natural grass** (50–60% moisture)

or

2.4 kg of **silage** (65% moisture)

Roughage

The moisture content of forage and silage vary widely.

- Freshly cut elephant grass contains about 80% water.
- Natural grasses contain about 50–60% water (less in the dry season). Younger grasses contain more water than mature ones.
- Silage contains about 65% water
- Hay contains about 16% water.

How much roughage to give

The amount of feed an animal needs depends on how much it weighs. In general, an animal needs to eat about 3.5% of its body weight of hay (or the equivalent amount of fresh forage or other forms of feed) each day. A 250 kg cow will need the equivalent of about 9 kg of hay a day.

Other animals need more or less feed, depending on their body size. An adult cow weighing 250 kg eats about as much as 10 goats. You can use the table on the next page to work out how much feed each type of animal needs. However, this is a rough guide only because animals' needs vary, and feeds vary widely in quality and water content. The cost of producing or buying the feed will also be an important factor in farmers' decisions.

Give extra feed, and better quality feed, to the following:

- Calves, lambs and kids, so they grow quickly and stay healthy. Give them as much roughage as they want.
- Pregnant and milking animals (give them 10–20% extra feed).
- Animals that are used for ploughing or other work.
- Animals that are sick or very thin.
- Improved breeds.

Combining types of roughage

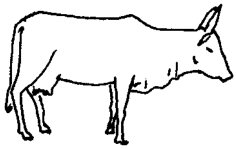
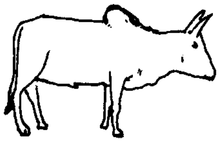
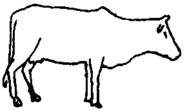
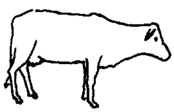
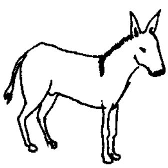
Do not feed animals on one type of roughage alone. Mix the different types. For example, you can feed a 250 kg cow with 4.5 kg of hay a day (half of what it needs), plus one of the following:

- 19 kg of freshly cut elephant grass, or
- 8–9 kg of natural grass, or
- 11 kg of silage, or
- 4 kg of natural grass *and* 5 kg of silage.

If you reduce the amount of hay, you should increase the amount of the other feed types. For example, you can feed the cow with 2 kg of hay, plus 6 kg of natural grass, plus 17 kg of elephant grass. See page 211 for how to calculate this.

For milking animals, provide at least 2/3 of the feed in the form of forage (rather than concentrate). This ensures that the milk is of good quality.

Approximate weights and daily feed of different animals

	Animal weighs about this much	It needs about this much hay (or the equivalent of other types of feed)
	Borana steer 350 kg	 12 kg
	Horo ox or adult Borana cow 300 kg	 10.5 kg
	Adult Horo cow 250 kg	 9 kg
	Borana heifer 200 kg	 7 kg
	Horo heifer 180 kg	 6.5 kg
	Growing calf 100 kg	 3.5 kg
	Donkey 200 kg	 7 kg
	Adult sheep or goat 25 kg	 0.9 kg
	Growing sheep or goat 20 kg	 0.7 kg

Important: Do not give the animal all its feed as hay. Give a mixture of types of roughage. See page 208 for the equivalent amounts of grass or silage.

All figures are for hay as feed with 16% moisture, not for “dry matter”.

Calculating how much forage to give

1 Check the number of kilograms of hay the animal needs each day (see the list on page 210).

2 Draw a number of circles: one circle for each kilogram of hay the animal needs (e.g., 9 circles for an adult Horo cow, 12 for a Borana steer).

3 Decide how many kilograms of **hay** you can feed each day. Write an **H** in the same number of circles.

4 For each of the **other types of fodder**, decide how many kilograms you can feed. Write the corresponding letter in an equivalent number of circles (**E** for elephant grass, **G** for natural grass, **S** for silage). Note that one circle corresponds to a different amount of each type of feed. So if you can feed 4.2 kg of elephant grass, write an **E** in just one circle.

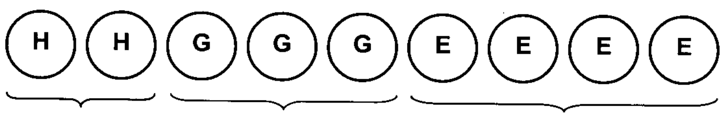
5 When you have filled all the circles, multiply the number of circles by the amount of feed it represents (see the examples). This is the feed combination that will be sufficient for that animal.

The calculations are for one animal only. Multiply by the number of animals of each type to get the total feed requirement.

○ = 1 kg hay (**H**)
or 4.2 kg fresh elephant grass (**E**)
or 2 kg natural grass (**G**)
or 2.4 kg silage (**S**)

Example 1

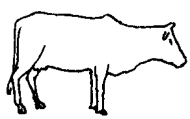
250 kg Horo cow
Requires equivalent of 9 kg of hay each day
Available feed = hay, natural grass and elephant grass.



2 x 1 = 2 kg of hay

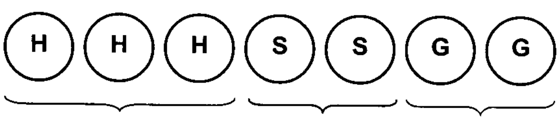
3 x 2 = 6 kg of natural grass

4 x 4.2 = 16.8 kg of elephant grass



Example 2

200 kg Borana heifer
Requires equivalent of 7 kg of hay each day
Available feed = hay, silage and natural grass.



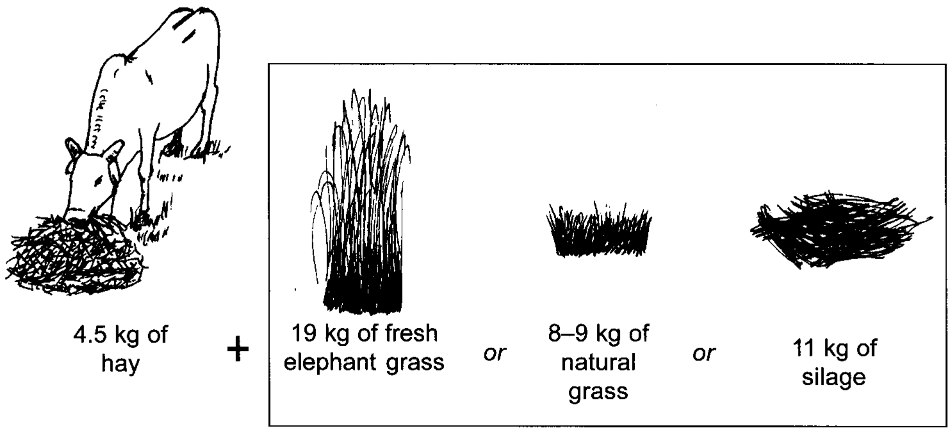
3 x 1 = 3 kg of hay

2 x 2.4 = 4.8 kg of silage

2 x 2 = 4 kg of natural grass

Note: figures are for hay as feed, not for "dry matter".

A 250 kg cow needs the equivalent of about 9 kg of hay each day, made up of different types of roughage. For example...



If you allow livestock to graze some of the time, you need to estimate how much extra feed they need. If the animals do not get enough feed from grazing, give them extra feed. If they clean out the feeding trough, give them some more. If they leave some feed uneaten, give them less on following days. Farmers can usually tell whether their animals still need more feed, and can judge how much to give them.

Concentrates and supplements

For high-producing animals such as dairy cattle, provide concentrates in addition to the roughage. Concentrates provide protein and energy, and help the animal grow and produce milk.

In general, a milk cow fed on enough medium-quality forage alone can be expected to produce about 5 litres of milk a day. Feeding it 1 kg of good concentrate mixture will produce an extra 2 litres of milk.

Provide a salt lick to animals fed by cut-and-carry, or mix a mineral supplement with concentrate.

Calculating how many animals to keep

If you have only a limited amount of land and cannot move your animals elsewhere, you need to calculate how many animals your land will support. To calculate this, you have to know:

- How much each animal eats.
- How much forage is available.

The 'stocking rate' is the number of animals kept on a hectare of land for a given period of time. Keeping too many animals results in overgrazing, damages the pasture, and may lead to erosion. Keeping too few animals means under-using the pasture.

Under good management, the stocking rate should just match the amount of forage that is available in the long term. This is called the 'carrying capacity' of the land.

The amount of forage produced will vary from one season to the next, and from year to year. That means the number of animals the land can support will also vary. If you have more animals than you can feed, try to sell some, move them to other pasture, or provide additional feed.

Drought reduces the amount of forage produced, so lowers the long-term carrying capacity.

Calculating the stocking rate

1 Estimate the area of pasture in hectares.
2 Count the number of animals of each type (cattle, horses, donkeys, goats, etc.).
3 Work out how many 'tropical livestock units' (TLUs) this is. Multiply the number of animals of each type by the number of TLUs for that animal. The box at the top of the next page shows how many TLUs to count for each type of animal.
4 Divide the total number of TLUs by the area of the pasture. This is the stocking rate.

See the box at the bottom of the next page for an example of calculating the stocking rate.

Measuring the amount of forage in a pasture

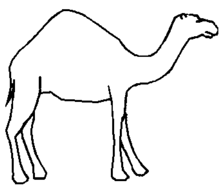
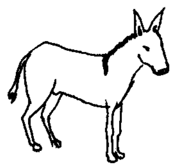
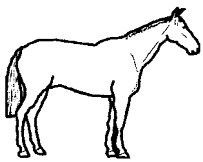
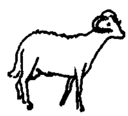
1 To measure the amount of forage a pasture produces, you must find a place that has not been grazed at the end of the season, when the plants have stopped grow-

Tropical livestock units

A 'tropical livestock unit', or TLU, is the equivalent of one average zebu cow, weighing about 250 kg. Larger animals, such as camels and bulls, eat more, so count as more than 1 TLU. Sheep and goats eat less, so are less than 1 TLU (see the list below).

TLUs are used in calculating the stocking rate and carrying capacity of pasture.

One TLU requires the equivalent of about 9 kg of hay per day, or about 3200 kg (3.2 tonnes) of hay per year.

		Tropical livestock units			Tropical livestock units
	Camel	1.2		Donkey	0.8
	Cow	1		Goat	0.1
	Horse	0.8		Sheep	0.1

Example of calculating a stocking rate

Type of animal	Tropical livestock units		No. of animals		Total
Cows	1	x	60	=	60
Horses and donkeys	0.8	x	30	=	24
Goats and sheep	0.1	x	250	=	25
Total Tropical Livestock Units				**=**	**109**

Area grazed = 96 ha

$$\textbf{Stocking rate} = \frac{109\ \text{TLU}}{96\ \text{ha}} = \textbf{1.14 TLU/ha}$$

ing and the grass is drying out. Suitable places include a stock exclusion area, a fodder bank, or a small area that has been fenced off.

2 Choose 3–6 places at random in the ungrazed pasture, for example by throwing a stick into the field and finding where it lands. It is important to choose the places at random, because if you select the best parts of the pasture, you will get an estimate that is too high.
3 At each place, use a tape or stick to measure a square 1 metre on each side.
4 Cut and collect all the forage from inside this square. Cut to the same height as animals normally graze. If the forage is not yet dry, allow it to dry in the sun.
5 Carefully weigh the amount of dry forage you have made in grams.
6 Use this formula to work out how much dry forage the pasture produces:

$$\begin{array}{c}\text{Total amount of dry forage}\\\text{(tonnes per hectare)}\end{array} = \frac{\text{Amount of sun-dried forage produced (kg)}}{\text{Number of squares sampled (m}^2\text{)}} \times 10$$

Example of measuring the amount of forage in a pasture

Number of metre squares sampled = 6

Total amount of sun-dried forage from sample squares = 3 kg

$$\textbf{Total amount of sun-dried forage per hectare} = \frac{3\text{ kg}}{6\text{ m}^2} \times 10 \quad \mathbf{= 5\ t/ha}$$

Working out how many animals a pasture can support

The number of animals a pasture can support (the 'carrying capacity') depends on the amount of forage it produces.

Animals will not be able to eat all of the forage in a pasture. They will trample on some, leave the less palatable plants, and not eat all of each plant. On average, they eat only about half of the forage available. Step 2 below takes this into account.

1 Multiply the amount of dry forage per hectare by the area of the pasture. This gives the total forage production for the whole pasture area.
2 Divide this number by 2 to get the amount of usable forage.
3 Divide the result by 3. This gives the number of tropical livestock units (average zebu cattle) the pasture can support for one year.

Important The actual carrying capacity may vary considerably, depending on the rainfall, the soil type, how much the animals actually eat, whether there are other sources of feed available (for example, if the farmer can herd the animals elsewhere), and many other factors. Use the results of these calculations as a rough guide only, and with caution.

Example of calculating the carrying capacity of a pasture

Actual number of animals	= 109 TLU
Area of pasture	= 96 ha
Dry forage production per hectare	= 5 t/ha
Total dry forage production	= 5 x 96 = 480 t
Usable forage	= 480 ÷ 2 = 240 t
Carrying capacity	= 240 ÷ 3 = **80 TLU**
Difference between actual number of animals and carrying capacity	= 109 – 80 = 29 TLU

Conclusion The farmer should sell 29 animals, or find additional sources of feed.

Note: figures are for hay as feed (or sun-dried grass), not “dry matter”.

Water

Animals can get some of their water needs from fresh forage. But all livestock (including goats) also need drinking water. If an animal is thirsty, it will eat less. It will not put on weight and milk yields will go down.

The amount of water an animal needs depends on:

- **Its size** Larger animals need more water.
- **The season** During the hot season, animals drink 20–25% more water.
- **The type of feed** Animals fed with dry hay need more water than those fed on fresh forage.
- **How it is kept** Animals that graze outside or that work need to drink more than ones kept in the shade.
- **Whether it is milking** Milking animals need more water than dry or male animals.

The table on the right gives approximate figures for the amount of water needed by different types of livestock.

Dairy cattle should always have water available to drink. If this is not possible, make sure they can drink as much as they want at least twice a day. A milking cow needs about 5–7 litres of water for every litre of milk it gives.

Camels need to drink less often than other livestock, but when they drink, they take in a large amount at one time.

Daily water needs of livestock

	Litres per day (minimum)
Cattle	25
Horses	20
Sheep and goats	10
Donkeys	20
Camels	50
Chickens (100 birds)	15
Pigs	15

Collecting runoff

In dry areas, there may be no rivers, ponds or lakes, and it may be too expensive to dig wells. It may be possible to collect runoff to water livestock. See page 160 for how to build ponds and storage tanks.

Collecting runoff can reduce the risk and potential impact of drought. Developing a water source means that the animals do not have to travel long distances in search of water. The water collected can be used to irrigate pasture and crops, allowing dry season grazing in some areas.

Water in zero-grazing

Water can be given to the animals in their shed, or the animals can be led to a water source to drink. Transporting water is hard work, so driving the animals to the water source is often easier. But this has disadvantages:

- The animals waste energy walking to the water source, so do not put on as much weight as if they were watered in the shed.
- They may trample the vegetation around the water source, and may contaminate it with mud and dung.

For animals kept under zero-grazing, it is better to provide water in the shed itself. This is possible if the water source is close by. Consider building a water tank close by the shed to collect water from rooftops (see *Water tanks*, page 166).

Provide enough water troughs so that all animals have access to water at any time. If the animals are kept in a paddock, not all animals will drink water at the same time. So if water is in the trough all the time, the trough need only be big enough for 10% of the animals to drink at one time.

It is important to keep water troughs clean to avoid spreading diseases.

Crop residues

Livestock can be allowed to graze on cropland immediately after the harvest, or the crop residue can be collected and fed to animals. Generally, cereal stalks (wheat, tef, barley, maize, sorghum) make poor-quality feed. However, the leaves make better quality feed than most natural grasses in the dry season. Mixing cereal stalks and leaves with pulse residues increases the quality of the feed.

Crop residues have various other uses. For example, farmers often use cereal stalks as fuel or building materials. Consider using the most nutritious parts of the plants (the leaves) as feed, and leaving the stalks on the land to enrich the soil.

To use crop residues as feed, collect them and stack them in a suitable place. Cover them to protect them from the sun and rain. If they get wet, they will go mouldy and lose quality.

Crop residues can be chopped up and mixed with molasses or treated with urea to make them more palatable and to improve their value as feed.

See page 222 for how to make hay, and page 225 for how to make silage.

Where to use crop residues as feed

Agroclimatic zones All zones where crops are grown.

Treating straw with molasses

Molasses are a sticky, thick, brown liquid, produced when making sugar from sugarcane. Straw treated with molasses is most often used to feed growing and fattening animals. Do not use molasses to feed milking cows.

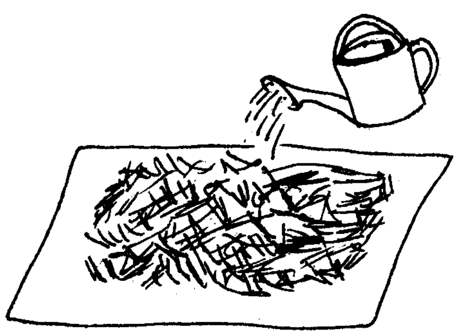
To treat straw, mix molasses with twice as much water, then sprinkle this on the crop residues. Alternatively, you can soak the residues in the water/molasses mixture overnight before feeding it. Treat only as much straw as you need each day.

Do not give more than 2 litres of molasses to each animal in a day.

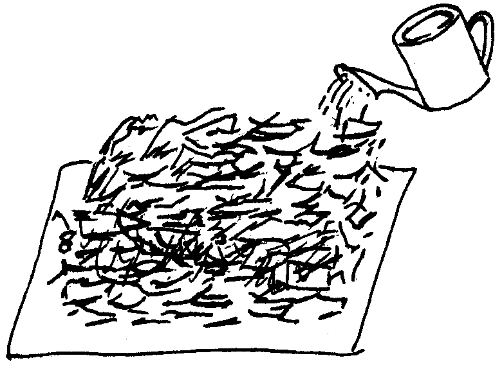
Treating straw with urea

Treating straw with urea before feeding it to the animals will help them gain weight.

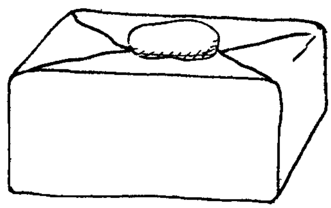
1 Spread a layer of chopped straw on a large, thick plastic sheet and sprinkle it with a mixture of urea and water.



2 Add another layer for straw and sprinkle with more urea and water. Repeat for several layers. For 100 kg of straw, you will need five 20-litre buckets of water and 6 kg of urea.



3 Wrap the plastic sheet over the top and sides of the pile so it is sealed completely. Put a stone on it to keep it airtight.



4 Leave for 3 weeks.
5 Before feeding, open the sheet and take out enough treated straw for a day or two. Cover the rest of the stack with the plastic sheet.
6 Leave the straw you have taken out for several hours (or overnight) so the ammonia smell disappears. The following morning you can feed it to the animals. Take some more straw out that evening to feed the next day, and so on.

Make sure the plastic sheet does not have holes in it, or the ammonia gas that is formed will escape, and the treatment will not be as effective.

You can use two piles to make a continuous supply of treated straw. Each pile should contain enough straw to last 3 weeks.

Caution

Do not use too much urea. It can poison the cows!

When you start to use the first pile for feeding, make a second pile the same size, following the steps above. After another 3 weeks, when the first pile is finished, you can start feeding from the second pile. Restart the first pile to make sure you have a continuous supply of straw.

Animals may not like to eat the treated straw at first. To begin with, mix it with other feeds. You can gradually increase the amount of treated straw. An adult cow can be given about 6 kg of treated straw a day.

Do not feed treated straw to calves younger than 6 months old.

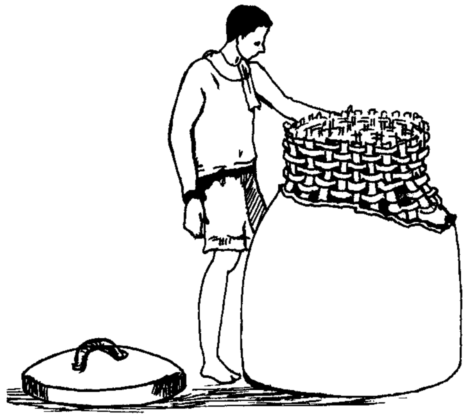
Straw is low in minerals, so provide a mineral lick in the shed.

Two more ways to treat straw

The method on the previous page uses a plastic sheet in a temporary location. If you plan to treat straw each year, you can use a permanent pit.

1 Dig a pit wide and deep enough to hold the straw you want to treat each day.
2 Line the floor and walls with plastic sheet.
3 Put layers of straw in, and sprinkle on a mixture of urea and water.
4 Cover the top of the pit with another plastic sheet.

You can also use a *rik*, a traditional grain-storage container made of bamboo. Plaster the container with clay, put the straw, water and urea in (see previous page), and close the top tightly.



A rik, cut away to show how it is made

Hay

Hay is forage that has been dried in order to conserve it. Good hay has 15–16% moisture content. It is greenish-yellow, smells pleasant, and contains many leaves. It should be cut at the right time for maximum yield and nutritive value.

Hay can be made from the following types of plants:

- **Forage grasses** such as Rhodes grass, Sudan grass and panicum. Cut them when half of the plants have started to flower.
- **Cereal grasses** such as oats and rye. Cut them when the grain is at the milk stage.
- **Forage legumes**. Cut alfalfa when 10–25% of the plants are in flower, or when the leaves are turning yellow. The best-quality hay comes from alfalfa cut in the bud stage or slightly before, but this early cutting may reduce the stand if done frequently. It can be cut every 30–40 days. Cut clovers when half of the plants are in flower.
- **Seed legumes** such as cowpeas, lentils, pigeonpea, broad bean and vetch. Cut them when the first pods are ripe, or wait until many of the pods are ripe.

Hay can be made with a mixture of these types of plants. You can also grow mixtures of crops (such as triticale and vetch) in the same field and harvest them together. Many types of plants can be cut several times to make hay.

Forages with a lot of leaves make better quality hay than stalks, so try to prevent the loss of leaves during drying, transportation and storage.

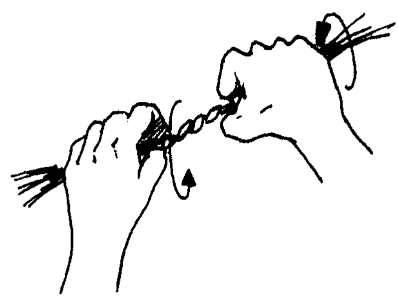
Where to use hay

Agroclimatic zones Moist Wurch; all Dega and Weyna-Dega; Moist and Wet Kolla.

Is the hay dry enough?

Here are two ways to tell if hay is dry enough.

- Scrape the skin from a hay stem with your fingernail. If it peels off, the hay is still too wet. Dry it some more.
- Take a few hay stems and twist them in your hands. If the stems break a little and no juice comes out, the hay is dry enough. If it does not break, or if you see juice, dry it some more.

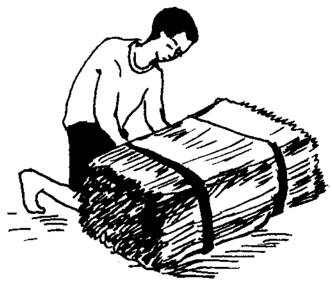


Haymaking

1 Plan to make hay when you can expect two days of fine, rain-free weather so the hay dries well. Harvest the forage in the morning, after the dew has dried off. Leave it in the field to dry.

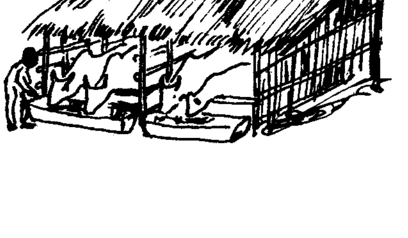
2 Before it is completely dry, rake it together into rows. Turn the piles over two or three times during the day. In the evening, rake the rows together into conical piles to protect as much of the hay as possible from dew. You can also use racks to dry the hay.

3 On the second day, wait until the dew has dried off, then spread the hay out to dry. Turn it over several times so it dries evenly. The leaves of legumes such as alfalfa and cowpea tend to fall off when exposed to the hot sun, so try to dry them in the shade.



4 When the hay is dry, make it into bales if possible, then carry it away.

5 Store the hay somewhere where it can be protected from the sun and rain. If possible, keep it in a barn or under a roof. If you store it outside, choose a shady place and build a haystack. Make the top of the stack sloping to keep off the rain, and cover it with straw, large leaves or plastic sheet.

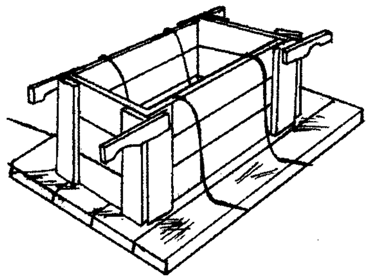


6 Feed the hay to the animals. Remove the hay from all around a circular stack (not just from one side) to prevent the stack from collapsing.

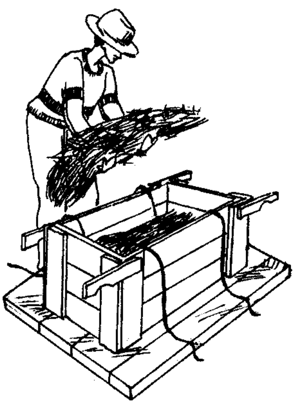
How to make hay bales

You will need a baling box of the size you want to make bales. The box has no bottom, but it should have handles so you can lift it easily. You may want to make a base to put the box on to make an even floor to work on. You will also need enough strong string to tie the bales.

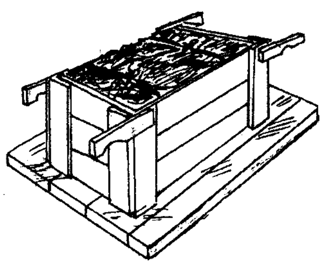
1 Put the string into the baling box so both ends hang out.



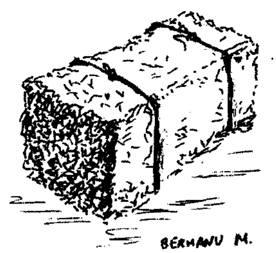
2 Put the hay into the pack and pack it down firmly.



3 Tie the strings very tightly.



4 Lift the baling box and remove the bale.



When feeding baled hay, make sure the animals do not eat the string (especially if it is made of plastic!) You can use it again to make more bales.

Silage

Silage is conserved feed that has been fermented without any air getting to it. It can be made by storing green forage in an airtight condition for 45–60 days. Silage can be stored for many months before feeding it to animals. The best silage feels dry (though it contains 65–75% moisture), has a pleasant, acidic smell, and is green-yellow. Medium-quality silage smells sweet and is dark brown. Poor-quality silage is olive-brown, slimy, smells foul, and animals do not like to eat it.

Suitable crops for silage include maize, sorghum and forage grasses. Using them to make silage means they cannot be used for grain, as the plants must be harvested before the seeds are mature (see below). Potato tops and sugar beet tops can be used for silage after their roots have been harvested.

If you plan to use crops such as maize and sorghum as silage, sow with 25–50% more seed than if you are growing them for grain.

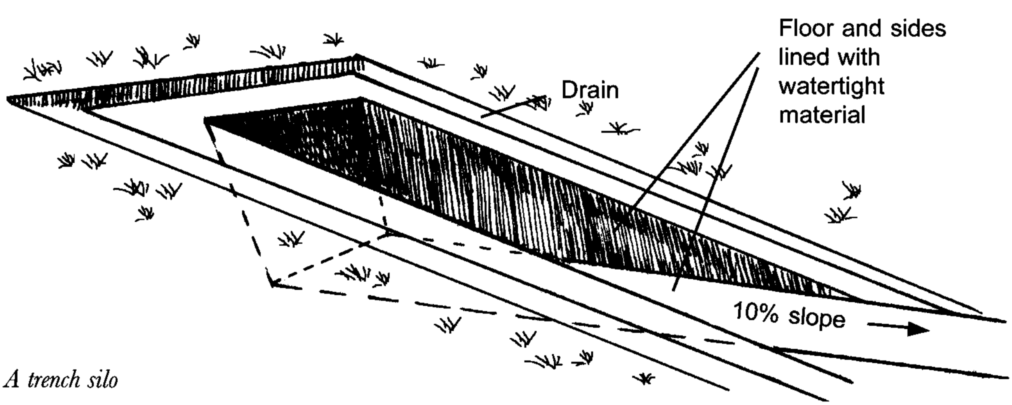
Where to use silage

Agroclimatic zones Moist and Wet Wurch and Dega; all Weyna-Dega; Moist and Wet Kolla.

Making a silo

A silo is where the silage is made and stored. Two types are useful for smallholders in Ethiopia: trench and circular. The silo protects the forage from rain and the air so it can ferment properly to make silage.

The smallest silos are 4–5 cubic metres (2 x 2 m, and 1 m high). Larger silos can be many times this size. The silo should be big enough to feed the animals throughout the dry season (also taking into account the other sources of feed available, such as hay and fresh forage).



A trench silo

Making a trench silo

A 10 cubic metre trench silo (4 m long x 1.5 m wide x an average of 1.6 m deep) can hold enough silage to feed two cows and two calves for 60 days.

1 Choose a site on a fairly steep slope with firm soil.
2 Dig a trench into the slope. The floor of the trench should have a 10% slope so water drains out easily. The sides should slope towards the middle of the trench.
3 Make drains to prevent water from flowing into the trench.
4 Line the floor and sides to make it watertight. You can use a thick plastic sheet, concrete or clay.

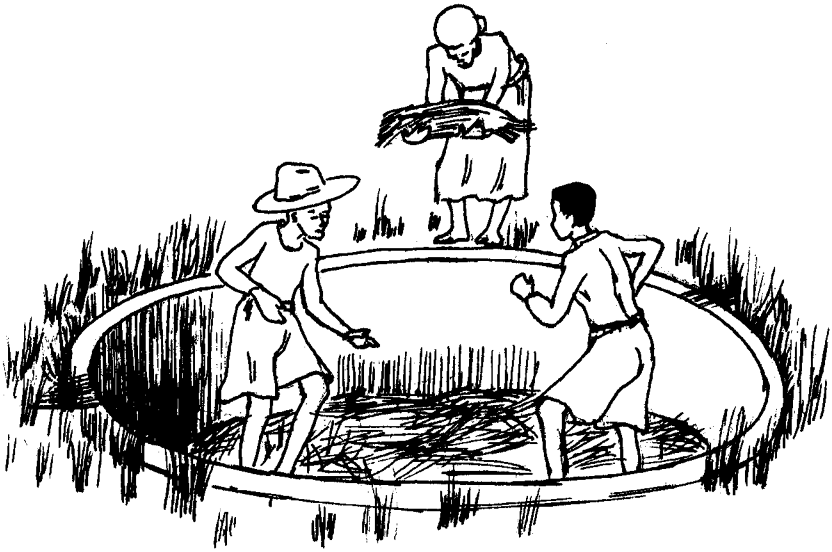
Making a circular pit silo

An 18 cubic metre circular silo can hold about 6000 kg of silage. This is enough to feed three cows (25 kg of silage a day) and three calves (6 kg a day) for 60 days.

1 Choose a well-drained site with firm soil.
2 Dig a circular pit 3.5 m in diameter and 2 m deep.
3 Plaster the wall with clay soil and cow dung, or line it with plastic sheet.
4 Put some big stones on the floor so any water can soak into the soil beneath.

Making silage

1 Harvest the crop to make silage from. The harvest time depends on the crop:
   - **Maize** 50–55 days after silking.
   - **Elephant grass** Before it reaches 1.5 m tall.
   - **Grasses** Before they flower.
   - **Oats** At the beginning of the dough stage.
   - **Shrubs** At the end of the rainy season.
2 Chop the forage into pieces about 3–5 cm long. Chopping by hand is too slow, so it is best to chop using a machine.
3 Test the moisture content of the forage. If moisture comes out when you squeeze it, it is too wet. Leave it for a few hours so it dries out a little.
4 Fill the silo with layers of chopped forage. Compact each layer well by treading on it. This is important to make good-quality silage.
5 For grasses, mix some molasses with twice as much water and sprinkle it on the layers of forage as you put them into the silo. You will need 35 litres of molasses mixture for every cubic metre of silage.
6 When the silo is full, cover the contents with a layer of straw, enset leaves, plastic sheet, or any other material that can stop air and water from getting in. Pile stones or a 30 cm layer of soil on top to keep the pile compacted. If you are using a circular pit silo, consider building a thatched roof over the pit to keep out the rain.
7 Leave the forage to ferment for 45–60 days.



Making silage in a circular pit silo

8 When ready, remove part of the covering and take out as much feed as needed for the day. Cover it again to keep out the air.

9 Give an adult cow 10–15 kg of silage per day. The animals may be unwilling to eat it at first, but they get used to it quickly.

Forage species

Forage species	Location	Cultivation
Trees and shrubs		
Calliandra *Calliandra calothyrsus*	0–2000 m altitude, above 1000 mm rain. Not drought-tolerant, but withstands 2–4-month dry periods. Grows on wide range of soils from deep volcanic to sandy clays. Poor tolerance of waterlogging.	Plant seedlings in beginning of rainy season. 0.5 m between plants and 1 m between rows. First cutting when tree is 2 m high. Good, fertile soil can give 4–5 harvests a year.
Leucaena *Leucaena* spp.	0–2000 m altitude, 500–750 mm rain. Likes fertile, well drained soils. Poor frost tolerance, very tolerant to drought, poor tolerance of waterlogging.	Plant seedlings June–July. Yields 10–14 t dry matter/ha. Matures in 12 months.
Pigeonpea *Cajanus cajan*	1500–1800 m altitude, 600–800 mm rain. Likes well-drained soils. Poor frost tolerance, very tolerant to drought, does not tolerate waterlogging.	Seeding rate: 20–25 kg/ha. Yields 5–8 t dry matter/ha. Plant in late June-early July. Matures in 5–6 months.
Sesbania *Sesbania sesban*	2000–2500 m altitude, 600–900 mm rain. Likes light, well drained soils. Medium frost tolerance, good tolerance of drought, medium tolerance of waterlogging.	Plant seedlings (or seeding rate: 10–15 kg/ha). Yields 8–12 t dry matter/ha. Plant in March–April. Matures in 12 months.
Tree lucerne *Chamaecytisus palmensis*	2300–3200 m altitude, 800–1000 mm rain. Likes light, well drained soils. Very good frost tolerance, medium tolerance of drought, does not tolerate waterlogging.	Plant seedlings March–April. Yields 10–12 t dry matter/ha. Matures in 12 months.
Herbaceous legumes		
Alfalfa *Medicago sativa*	1800–2000 m altitude, 600–850 mm rain. Likes fertile non-acid soils. Tolerates frost and drought. Does not tolerate waterlogging.	Seeding rate: 8–10 kg/ha. Yields 5 t dry matter/ha. Plant in June–July. Matures in 5–6 months.
Axillaris *Macrotyloma axillare*	1800–2000 m altitude, 600–850 mm rain. Likes a wide range of well drained soils. Does not tolerate frost, drought or waterlogging.	Seeding rate: 5 kg/ha. Yields 4–5 t dry matter/ha. Plant in June–July. Matures in 5–6 months.

Note: "Dry matter" is a measure of forage weight when all the water is dried out of it in an oven. It is drier than sun-dried hay.

Forage species	Location	Cultivation
Caribbean stylo *Stylosanthes hamata*	1800–2000 m altitude, 600 mm rain. Likes light sandy and acidic soils. Does not tolerate frost and waterlogging, drought tolerant.	Seeding rate: 5 kg/ha. Yields 3–4 t dry matter/ha. Plant in March–April. Matures in 6 months.
Cowpea *Vigna unguiculata*	1800–2200 m altitude, 300–600 mm rain. Likes light to heavy soils. Does not tolerate frost and waterlogging, drought tolerant.	Seeding rate: 10–20 kg/ha. Yields 6.4 t dry matter/ha. Plant in June/July. Matures in 4–5 months.
Greenleaf desmodium *Desmodium intortum*	1800–2200 m altitude, 600–850 mm rain. Likes well drained soils. Poor frost tolerance, medium tolerance of drought and waterlogging.	Seeding rate: 5 kg/ha. Yields 6 t dry matter/ha. Plant in June–July. Matures in 5–6 months.
Lablab *Lablab purpureus*	1800–2000 m altitude, 600–800 mm rain. Likes a wide range of soils. Does not tolerate frost and waterlogging, drought tolerant.	Seeding rate: 15-20 kg/ha. Yields 4–5 t dry matter/ha. Plant in June/July. Matures in 5 months.
Silverleaf desmodium *Desmodium uncinatum*	1800–2200 m altitude, 600–850 mm rain. Likes well drained soils. Does not tolerate frost, medium tolerance of drought, does not tolerate waterlogging.	Seeding rate: 5 kg/ha. Yields 6 t dry matter/ha. Plant in June–July. Matures in 5–6 months.
Shrubby stylo *Stylosanthes scabra*	1800–2000 m altitude, 600 mm rain. Likes light sandy and acidic soils. Does not tolerate frost and waterlogging, drought tolerant.	Seeding rate: 5–8 kg/ha. Yields 3–4 t dry matter/ha. Plant in March/April. Matures in 6 months.
Siratro *Macroptilium atropurpureum*	1800–2000 m altitude, 600–800 mm rain. Likes drained soils. Does not tolerate frost and waterlogging, medium tolerance of drought.	Seeding rate: 3–5 kg/ha. Yields 5.1 t dry matter/ha. Plant in June/July. Matures in 5–6 months.
Vetch *Vicia varia*	2300–3000 m altitude, 600–1000 mm rain. Does not tolerate frost. Medium tolerance of drought and waterlogging.	Seeding rate: 15–20 kg/ha. Yields 6–8 t dry matter/ha. Plant in early June. Matures in 4 months.
White clover *Trifolium repens*	2500–3000 m altitude, 800–1000 mm rain. Likes variable soils. Medium tolerance of frost, does not tolerate drought, tolerates waterlogging.	Seeding rate: 2–3 kg/ha. Yields 5-6 t dry matter/ha.
Other plants		
Fodder beet *Beta vulgaris*	1800–3000 m altitude, 750 mm rain. Likes sandy soils. Tolerates frost and drought very well, does not tolerate waterlogging.	Seeding rate: 5 kg/ha. Yields 8–12 t dry matter/ha. Plant in June. Matures in 6 months.

Forage species	Location	Cultivation
Oldman saltbrush *Atriplex nummularia*	<1500 m altitude, 200 mm rain. Likes a wide range of soils. Does not tolerate frost and waterlogging, drought tolerant.	Plant seedlings using 2 m x 1 m spacing.
Spineless cactus *Opuntia ficus-indica*	<1500 m altitude, 200–400 mm rain. Likes well drained red limestone soils. Does not tolerate frost and waterlogging, drought tolerant.	Yields 6–30 t dry matter/ha.
Grasses		
Buffel grass *Cenchrus ciliaris*	<2000 m altitude, 600 mm rain. Likes light rains. Does not tolerate frost and waterlogging, drought tolerant.	Seeding rate: 3–5 kg/ha. Yields 5 t dry matter/ha.
Common oats *Avena sativa*	<3500 m altitude, 800 mm rain. Likes light to heavy soils. Tolerates frost and waterlogging, medium drought tolerance.	Seeding rate: 75–100 kg/ha. Yields 7–12 t dry matter/ha. Plant in early June. Matures in 4–5 months.
Elephant grass *Pennisetum purpureum*	<2400 m altitude, 1100 mm rain. Likes deep alluvial soils. Poor tolerance of frost, drought tolerant, does not tolerate waterlogging.	Plant cuttings mid-June. Yields 10–15 t dry matter/ha. Matures in 6–8 months.
Gatton panic *Panicum maximum*	<2000 m altitude, 800 mm rain. Likes fertile soils. Medium tolerance of frost, drought and waterlogging.	Seeding rate: 3 kg/ha. Yields 6–10 t dry matter/ha. Plant in early May. Matures in 6 months.
Guinea grass *Panicum maximum*	<2000 m altitude, 900 mm rain. Likes very fertile soils. Does not tolerate frost, medium tolerance of drought and waterlogging.	Seeding rate: 3 kg/ha. Yields 16 t dry matter/ha. Plant in early May. Matures in 6 months.
Phalaris *Phalaris aquatica*	1800–3000 m altitude, 800 mm rain. Likes fertile soils. Tolerates frost, drought and waterlogging.	Seeding rate: 2 kg/ha. Yields 6–8 t dry matter/ha. Plant in early May. Matures in 6 months.
Rhodes grass *Chloris gayana*	<2200 m altitude, 600 mm rain. Likes a wide range of soils. Medium tolerance of frost, drought and waterlogging.	Seeding rate: 3 kg/ha. Yields 7–12 t dry matter/ha. Plant in early May. Matures in 6 months.
Setaria *Setaria sphacelata*	<2200 m altitude, 700 mm rain. Likes a wide range of soils. Medium tolerance of frost and drought, tolerates waterlogging. Suitable for all strategies.	Seeding rate: 3 kg/ha. Yields 6–8 t dry matter/ha. Plant in early May. Matures in 6 months.

Note: "Dry matter" is a measure of forage weight when all the water is dried out of it in an oven. It is drier than sun-dried hay.

8

Managing trees and shrubs

Farmers plant trees and shrubs for different purposes:

- **Production** To produce poles, timber, fuelwood, charcoal, fruit, fodder, honey and other products.
- **Protection** To protect the soil, improve soil fertility, provide shelter and shade, or fence animals out of fields.

Trees and shrubs can be grown in large-scale plantations, which are usually managed by the government, or by individual farmers and communities. This chapter deals only with trees planted by individual farmers or communities.

What type of trees and shrubs to grow, and how to manage them, depend on the site and the purpose of growing them. For example, you might consider planting *Grevillea robusta* or cypress if you wish to produce timber, cypress or eucalyptus if you need poles, or eucalyptus or acacia for fuelwood. Chapter 9 lists various tree and shrub species and their uses. Planting a mixture of species spreads risks and produces a range of products.

This chapter covers how to collect and store tree and shrub seeds, how to start a nursery and care for seedlings, how to plant trees and shrubs for various purposes, and how to manage them after planting.

To make the text shorter and easier to understand, it uses the word "trees" rather than the longer "trees and shrubs". In many places, however, the word "trees" refers to both.

Collecting and storing tree seeds

Tree nurseries require good-quality seeds, in adequate amounts. The seeds must be of the right species, and from the right source.

Some types of seeds must be handled in a certain way. This section gives some general guidelines that apply to all types.

Where to collect and store tree seeds

Agroclimatic zones All.
Soils All.

Advantages of collecting and storing tree seeds

- Unless you already have seeds available, you will have to secure a seed supply if you want to start a tree nursery.
- Storing seeds may be necessary if it is not possible to plant them immediately.

Disadvantages and constraints

- If seeds are not collected and stored properly, they may fail to grow. Or they may develop into poor-quality seedlings that do not grow well.
- Planting trees is a long-term investment. Farmers will do it only if they think that they, or their families, can benefit.

How to collect seeds

Good seeds grow into good trees, and poor seeds produce poor trees. Seeds from a straight tree produce straight trees, while seeds from a twisted tree grow into twisted trees. The best seeds come from parent trees that are strong and healthy.

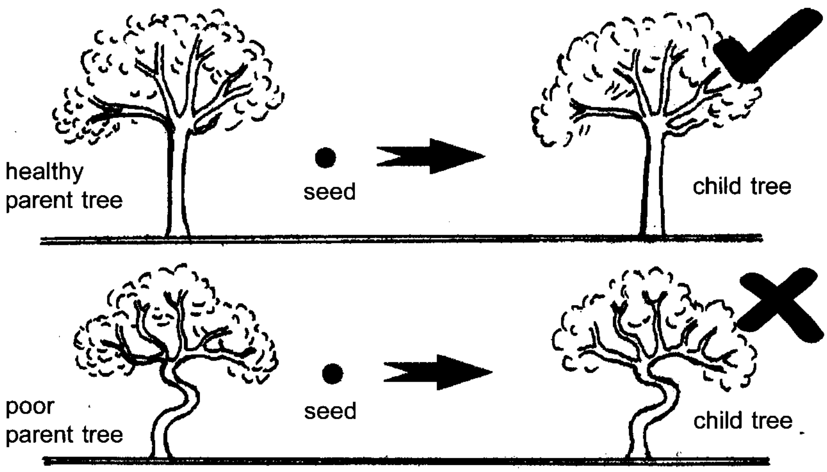
Collect seeds from areas at a similar altitude, and with the same soil type and rainfall as where you want to plant the seedlings.

You can collect seeds from trees that have been felled, or from standing trees. When you collect seeds from standing trees, make sure you do not damage the mother tree. Only cut small twigs and branches, never the leading shoot.

You need to know the time of the year when different species of trees flower and set seed, so that you can plan to collect the seeds. Rains affect when trees flower and fruit. This means the best time to collect seeds is different from one place to another.

Seeds from healthy, straight trees produce good timber trees.

Seeds from poor and diseased trees produce poor timber trees.



Collect large, healthy seeds, as soon as they are ripe. A delay means that birds may eat them, or insects may damage them. Pick fully ripe fruits directly from the tree, or collect them on the ground each day as they fall. Seeds that have been on the ground for a long time may be spoilt.

Seeds that fall from the tree are normally ripe. Do not collect the ones that fall first (they may be unripe), or those that fall last (they may be spoilt).

How to remove seeds from the fruit or pod

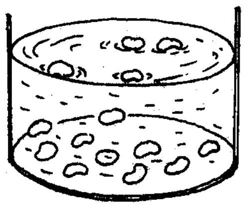
Ripe seeds that you collect from the ground or from standing trees are usually ready to sow or to store immediately. But the seeds of some species must be separated from the fruits or pods that contain them. There are various ways of doing this.

Dry cones and pods

For legumes which produce pods, and for eucalyptus and other cone-bearing species, dry the pods or cones in the air until they open. Then rake, roll or beat them carefully on a clean, dry surface to separate the seeds. Clean them by hand or by winnowing them in a gentle wind. The wind will blow empty seeds away.

Pulpy or fleshy fruits

Dry these fruits in the air. You can also soak seeds in water to allow the fleshy parts to separate. Then crack the hard shell to remove the seed. Empty seeds normally float in water, while good seeds sink to the bottom. Take the good seeds out of the water and dry them in the air.



Empty seeds float; good seeds sink.

How to treat seeds

Most seeds germinate if the moisture and temperature is right. But some seeds go into dormancy, and do not germinate unless this dormancy is broken. These seeds must be treated before they can be sown.

Some seed coats are hard and do not let water through, and will not germinate unless the coat is softened. Usually, you can do this by soaking the seed in water. You can also scratch or crack the seed coat (see page 187).

Different species respond best to certain treatments, or to a combination of treatments. Here are some common methods.

Soaking in hot water

Examples *Acacia albida, Parkinsonia aculeata*

1 Boil some water in a pan large enough to hold 2–3 times the amount of seed.
2 Remove the pan from the fire and let it cool for 5 minutes.
3 Put the seeds into the water and leave it there for 12 hours.
4 Sow the seeds immediately, without letting them dry.

Soaking in cold water

Examples *Olea europaea* ssp *africana* (*woira*), *Acacia nilotica*
Soak the seeds in cold water for one or more days before sowing.

How to store seeds

It is best to sow seeds soon after collecting them, but this may not always be convenient or practical.

- You may have to sow on a particular date to produce seedlings of the right size at the beginning of the planting season.
- Seeds of certain species germinate only after they have been stored.
- Some years are good for seeds, while others are not. It is a good idea to store seeds from the good years to use in the bad years.

To store seeds, first dry them (wet seeds will rot). Extreme heat kills seeds, so never dry them in direct sunlight.

Once the seeds are dry, store them in dry containers, such as jars or bags, in a cool place. To keep insects and damp away, keep the containers off the floor and away from the wall. Allow air to circulate around the containers.

Label each container properly. Write on it the seed species, where and when it was collected, and the number of seeds in the container.

Some seeds are very small, while some are quite large. One kilogram of eucalyptus seed might contain up to 1,000,000 individual seeds, while 1 kg of *Olea europaea* spp *africana* (*woira*) seed might contain only 10,000 seeds. Remember this when working out how many seeds you will need for a nursery.

Tree nurseries

Nurseries are used to produce seedlings for many purposes: to plant new forests and woodlots, to grow around houses and farms, and to reclaim degraded land. The nursery is an important part of a production system that creates new tree and forest resources.

Where to use nurseries

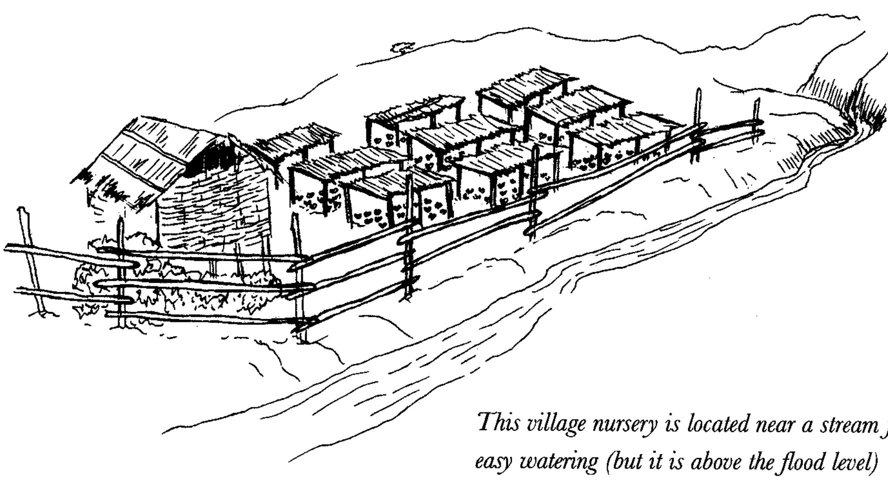
Agroclimatic zones All areas where trees are grown.
Soils All.

Advantages of nurseries

- Nurseries are necessary to produce seedlings. Other methods, such as sowing the seeds directly, or transplanting seedlings that grow wild, are too unreliable and cannot produce large numbers of uniform trees.

Disadvantages and constraints

- Establishing a nursery is a lot of work – perhaps too much work for one family. A lot of commitment is needed on the part of the farmer.
- The nursery may produce more seedlings than the farmer can use (though he or she may be able to sell the seedlings).
- It may be necessary to organize a group of farmers to establish and care for a nursery.



This village nursery is located near a stream for easy watering (but it is above the flood level)

Types of nurseries

There are two types of nurseries, permanent and temporary.

- Large, **permanent nurseries** can produce millions of seedlings. They are known as 'central nurseries', and supply large areas with seedlings. These nurseries are the type that the government and NGOs run.
- A **temporary nursery** can supply smaller areas with seedlings. Individual farmers often use small nurseries to produce seedlings for their own use. Ethiopia has many such nurseries. A typical nursery covers only a few square metres and produces a few hundred bare-rooted eucalyptus seedlings.

The rest of this section deals with temporary nurseries.

Where to site a nursery

Choose the nursery site very carefully.

- The area should be flat, but avoid sites that are waterlogged or subject to flooding.
- It must have easy access to a reliable source of water (a stream or well close by is ideal).
- It must be large enough for the seedbeds, and have space for storing and mixing soil. An area of 10 x 10 metres is normally enough.
- Consider the ownership of the land to avoid conflicts.

Clear the nursery areas of all vegetation and fence it with thorny branches to keep out grazing animals.

Shade

Young seedlings must be protected from direct sunlight. You can provide shade by building frames over the seedbeds. The shade should be a bit wider than the bed itself to avoid any unshaded areas along the edges of the bed. The frames should be easily removable. The shade should not be complete: use a material that gives about 50% shading. Do not use a thick layer of grass, as this provides too much shade, and produces damp conditions that may encourage diseases.

Growing tree seedlings

There are two methods of raising tree seedlings:

- **Bare-rooted** The seeds are sown in an open bed. When they are ready for transplanting, they are lifted from the soil so the roots are bare, then taken to where they are to be planted (see page 237).
- **In pots** The seeds are sown in individual containers. When the seedlings are ready for planting, they are taken in these pots to the planting site, and then planted with a ball of soil around their roots (see page 241).

Bare-rooted seedlings

Bare-rooted seedlings are grown in a nursery bed, then gently uprooted and taken to where they are to be planted. This method works well in cooler areas and in moist or wet zones. It is less suited to areas with high temperatures, dry conditions, and where the start of the rainy season is hard to predict.

Where to use bare-rooted seedlings

Agroclimatic zones Moist and Wet Wurch, Dega, Weyna-Dega and Kolla.
Soils All.

Advantages of bare-rooted seedlings

- Bare-rooted seedlings are easier and cheaper to grow than seedlings in pots.
- They are lighter than seedlings in pots because they have no soil attached to their roots. That makes them easier to transport to the planting site.
- Bare-rooted seedlings do not need a large amount of soil as (unlike with potted seedlings) no soil is taken in or out of the nursery.

Disadvantages and constraints

- Bare-rooted seedlings can be used only for a few hardy species such as *Eucalyptus*, *Prosopis* and *Azadirachta indica*.
- The seedlings may dry out during lifting, transportation and just after planting.

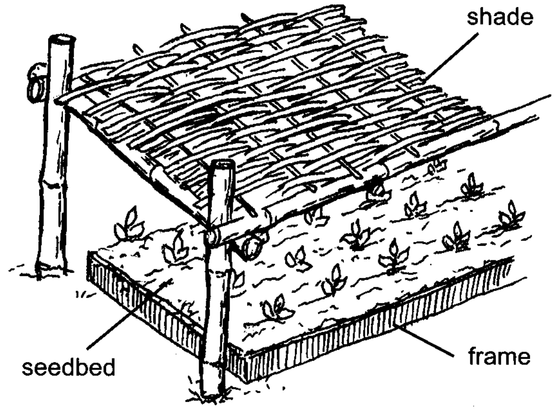
How to grow and plant bare-rooted seedlings

Follow these steps to grow and plant bare-rooted seedlings.

1 Prepare seedbeds in the nursery.
2 Sow the seeds.
3 Care for the seedlings.
4 Transplant the seedlings.
5 Lift the seedlings to prepare for planting.
6 Plant the seedlings.

1 Prepare the seedbeds

The soil in the seedbed must be light to help germination and to produce good quality seedlings. Make it from a mixture of one part of sand and an equal amount of forest soil to ensure good drainage. This light mixture crumbles easily when the seeds are germinating.



A raised seedbed under a bamboo shade

1 Make a frame for the seedbed from bamboo or stones. It can be 10 m long, but not more than one metre wide, so you can reach the middle easily. It should be about 20 cm high, and buried 5 cm into the ground.
2 Cover the bottom of the bed, inside the frame, with a 5 cm layer of stones or broken bricks. Cover this layer with 2–3 cm of unsieved forest soil.
3 Add sieved forest soil mixed with the same amount of sand (50–50 mixture) to just below the top of the frame.
4 Make sure that the surface of the bed is flat and firm. You can use a piece of flat board to level the surface.
5 Build a loose roof of bamboo or other material over the seedbed to shade it.

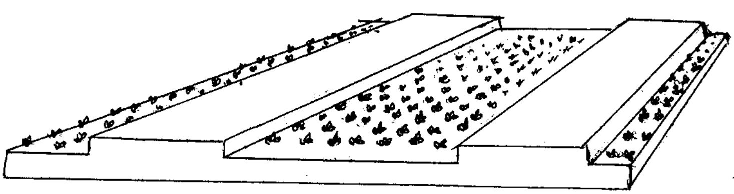
2 Sow the seeds

When is the best time to sow seeds? Count back from the beginning of the rainy season the number of months needed to raise seedlings that are big enough to plant. The length of time depends on the species and the local climate. Be sure to include the germination time – this varies considerably from species to another.

1 Sow the seeds at the same depth, and spread them evenly and thinly in the seed-

Sunken seedbeds

In dry areas and in sandy soils, you can sink the beds into the ground. This is a simple way of making a seedbed. Do not make sunken beds in wet areas because water may collect in them and kill the seedlings.


A sunken seedbed

bed. A good way to avoid sowing small seeds too thickly is to mix one measure of seed with two measures of fine sand. Mix the seeds and sand thoroughly, then broadcast this mixture over the surface of the seedbed.

2 Cover the seeds with sand or sieved soil, to twice the depth of the size of the seeds. For small seeds such as eucalyptus, you need a very light covering.

3 Gently firm the seedbed again. This stops the seeds from moving when the seedbed is watered.

For larger seeds, make holes across the seedbed and sow the seeds individually.

3 Care for the seedlings

Keep the seedbeds moist by watering them with a fine spray. Remove weeds using a pointed stick. If the seeds germinate too closely, thin them out.

4 Transplant the seedlings

Transplanting means moving seedlings from the seedbed into an open transplant bed (or into pots) to give them more space. This takes place when the seedlings reach the proper size – for most species, about 3–5 weeks after germination. The timing is important because very young seedlings are sensitive and can easily be damaged. Old seedlings stop growing because of the shallow soil in the seedbed, or because they run out of space.

1 Prepare a transplant bed (or enough pots) to transplant the seedlings into. A transplant bed should be made just like the seedbed (see above). See page 241 for how to prepare the pots.

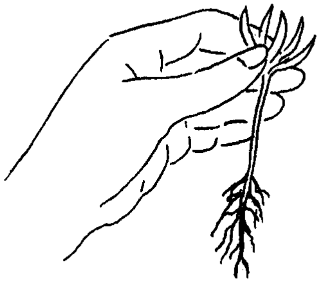
2 The day before transplanting, water the seedbed thoroughly. This makes it easy to lift the seedlings without damaging them.

3 Lift each seedling carefully, holding it by the top of a leaf and not by the soft stem. Keep the seedlings under shade, as the roots are sensitive to sunlight. Do not lift too many seedlings at a time.

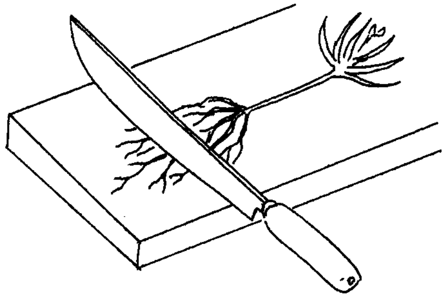
4 If necessary, cut the taproots with a sharp knife. This is particularly important if the seedlings have been left for too long in the seedbed and the taproots are bent.

5 Transplant the seedlings into the transplant bed (or pots). Plant them in rows at least 20 cm apart, with 10–15 cm spacing within the rows. Seedlings need space to grow; some species need more light than others, and some grow faster than others.

6 Keep the transplanted seedlings shaded. Water them regularly.



Hold the seedling by a leaf, not the stem



Cut the roots with a sharp knife, razor blade or scissors

7 Leave the seedlings in the transplant bed until they are planted in the field.
8 Gradually remove the shade as the seedlings grow older so by the time they are ready to transplant they are used to growing in full sunlight.

5 Lift the seedlings to prepare for planting

1 One month or so before the time of planting, reduce the watering frequency to harden the seedlings. For instance, if you have been watering twice a day, you can reduce it to once a day, and eventually, once in two days, and so on.
2 A day before removing seedlings from the transplant bed, water the seedbed thoroughly to make it easy to remove the seedlings.
3 Remove seedlings from the transplant bed, and separate their roots from the soil. Be careful not to damage the roots.
4 Put the seedling roots in bags to protect them from direct sunlight. Keep them wet if possible. Once lifted, the roots can dry out, so lifting and planting are best done on the same day.

6 Plant the seedlings

It is best to plant seedlings at the beginning of the rainy season, so the seedlings have enough moisture to become established.

1 Prepare the planting sites before lifting the seedlings (see above). Decide where you want to plant each seedling, and if necessary, clear vegetation from around each planting spot. In dry areas, it may be necessary to make microbasins around each planting spot (see page 133).
2 Dig holes considerably larger than the root length. About 60 cm across and 30 cm deep is ideal.
3 Lift the seedlings and transport them to the site (see above).
4 Plant the seedlings in the holes, compact the soil around the seedlings, and if possible, water them.
5 Protect the seedlings from grazing animals by putting woven cages or thorny branches around each seedling.

Growing seedlings in pots

Seedlings can be grown in polythene pots, or in plastic bags, segments of bamboo or other containers. The seedlings are taken to the planting site in the containers, with the soil still attached to the roots. This protects the seedlings and helps them survive. Growing seedlings in pots is common in Ethiopia.

Where to grow seedlings in pots

Agroclimatic zones Suitable in all zones, but not necessary in better sites where cheaper, bare-rooted seedlings can be used with the same results (see page 237).

Soils All.

Advantages of growing seedlings in pots

- The roots of the seedlings are not easily damaged when they are transported and planted.
- It is possible to delay planting by pruning the roots of seedlings grown in pots. (Bare-rooted seedlings grown in a seedbed must be planted before their roots grow down deep into the soil of the seedbed.)

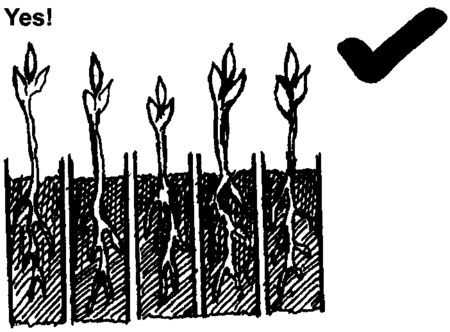
Disadvantages and constraints

- Seedlings in pots are heavier and more difficult to transport than bare-rooted seedlings.
- They need more initial investment (for the pots) and more access to suitable planting soil than bare-rooted seedlings.

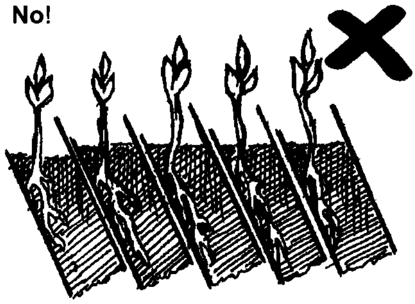
How to grow seedlings in pots

Follow these steps to grow and plant seedlings in pots.

1. Obtain the soil.
2. Prepare the pots.
3. Sow the seeds.
4. Care for the seedlings.
5. Pack and transport the seedlings.
6. Plant the seedlings.



Place the bags vertically



Wrong placement

1 Obtain the soil

The potting soil should be light, fertile, have a high organic matter content, and retain water well. You can add NPK fertilizer to improve the soil fertility. The soil must be cohesive. You can make suitable potting soil by mixing one part of sand, one part of clay, and one part of animal manure or compost (1:1:1 mixture).

2 Prepare the pots

You can use polythene pots, or other sorts of containers: bags, boxes, tins and bamboo segments. The containers can be of various sizes, but not smaller than 18 x 6 cm.

Avoid large pots because they take more space, require more soil and water, and are harder to fill and move to the planting site. However, large pots are useful in harsh planting sites, because they can hold more water for the plant, giving it a good start.

Fill the pots with nursery soil. Shake the pot while filling it, to stop air pockets from forming inside. Firm the soil as you fill. The pots should be filled to the top. Stack them side by side in straight, even rows.

Make sure that the pots stand upright. This stops the roots from growing down the side of the pot and becoming deformed.

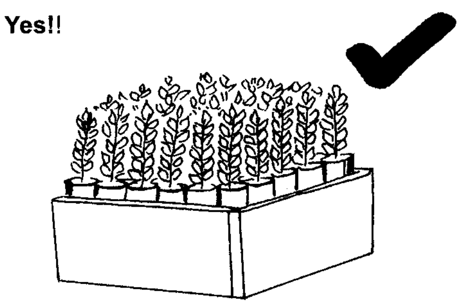
3 Sow the seeds

You can sow seeds directly into the pot. Or you can sow the seeds in germination beds and later transplant them into the pots. Both methods are widely used.

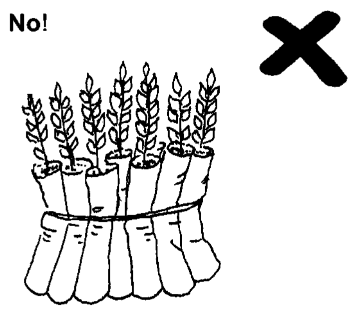
Sowing seeds first in a seedbed gives a more favourable environment for germination, so produces better results. On the other hand, sowing directly into the pots is cheaper and easier – it avoids the need to make a special seedbed and to transplant the young seedlings.

See page 237 for how to sow in seedbeds.

1. Before sowing directly into the pots, leave the filled pots to stand for a few days. The soil will then settle, making enough room for the seed and the soil to cover it. Water the pots a day before sowing.
2. Sow the seed and cover it with sand or a mixture of sand and sieved soil. The number of seeds to sow in each pot depends on how easily the seeds you have germinate. You may know this from experience, or you can test a few seeds before-



You can arrange seedlings in a box



Do not tie seedlings together

hand to see what proportion germinate. In some pots, no seeds may germinate; in others, several may do so. After germination, transplant seedlings between the pots so that all pots contain seedlings.

4 Care for the seedlings

Water the pots with a fine spray to keep them moist. Use a pointed stick to remove weeds. Keep the pots under shade.

To stop taproots from growing out of the pots, move the pots every two weeks. Check the growth of the taproots regularly. Use a sharp knife to cut taproots that grow out of the pots.

Gradually remove the shade as the seedlings grow older so by the time they are ready to transplant they are used to growing in full sunlight.

5 Pack and transport the seedlings

When you are ready for planting, pack the potted seedlings in small wooden boxes. Keep the seedlings in the pots: the earth-ball around the roots protects them during transport and helps the seedlings establish themselves more quickly.

6 Plant the seedlings

It is best to plant seedlings at the beginning of the rainy season, so the seedlings have enough moisture to become established.

1 Prepare the planting sites before packing the seedlings (see above). Decide where you want to plant each seedling, and if necessary, clear vegetation from around each planting spot. In dry areas, it may be necessary to make microbasins around each planting spot (see page 133).
2 Dig holes considerably larger than the root length. About 60 cm across and 30 cm deep is ideal.
3 Pack the seedlings and transport them to the site (see above).
4 Carefully remove the seedlings from the pots and put them gently into the holes. Compact the soil around the seedlings, and if possible, water them.
5 Protect the seedlings from grazing animals by putting woven cages or thorny branches around each seedling.

Trees and shrubs on and around farms

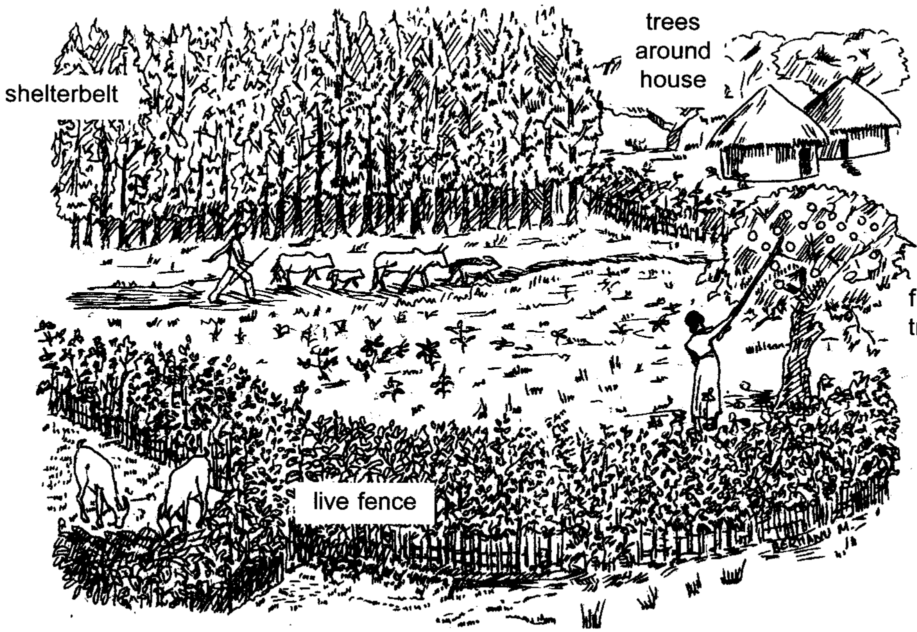
Farmers can plant trees and shrubs around their houses and on unused pieces of land. Empty land can be found along roads and streams, along the boundaries of fields or farms (as live fences), around schools and churches, at the corners of fields, etc. Farmers may also set aside land to grow fruit trees or shelterbelts (windbreaks).

Where to grow trees on farms

Agroclimatic zones All Wurch, Dega, Weyna-Dega, Kolla and Bereha.
Soils All.

Advantages of trees on farms

- Trees can make unused land productive.
- Trees provide shade and protection from the wind.
- Live fences mark boundaries and keep livestock out.



The shelterbelt in the background provides shade and protection from the wind, and can be used as a source of fuelwood. The live fences in the foreground keep animals out of fields and mark property boundaries. Trees around the houses produce fruit and provide shade.

Disadvantages and constraints

- Trees can interfere with crops if they are planted too close to fields, or if they are poorly managed. For example, they can provide too much shade, and may compete for soil nutrients. The roots may interfere with ploughing.
- Eucalyptus uses a lot of water, and may lower the groundwater table. Planting sites must be chosen carefully.

How to care for trees on farms

Weed around newly planted seedlings and protect them from grazing animals (see page 243).

Take out the smaller, weaker trees as the plantation matures (see page 253).

Replace older and mature trees with fresh seedlings as required. For example plant a new row of seedlings parallel to the existing ones in a shelterbelt, then harvest the older trees. Fell the larger trees when they have reached harvestable size. When felling trees, make sure they do not damage smaller trees as they fall.

Some types of trees can also be renewed by coppicing (see page 254).

Plant new trees to fill in any gaps in live fences and shelterbelts. Planting several species (for example, tall trees and shrubs) together may be necessary to form a solid barrier.

To take full advantage of trees, treat them as part of agricultural production. For example, they can be pruned for mulch (page 94), cut for feed (page 200), or browsed by animals.

Trees and shrubs to rehabilitate degraded land

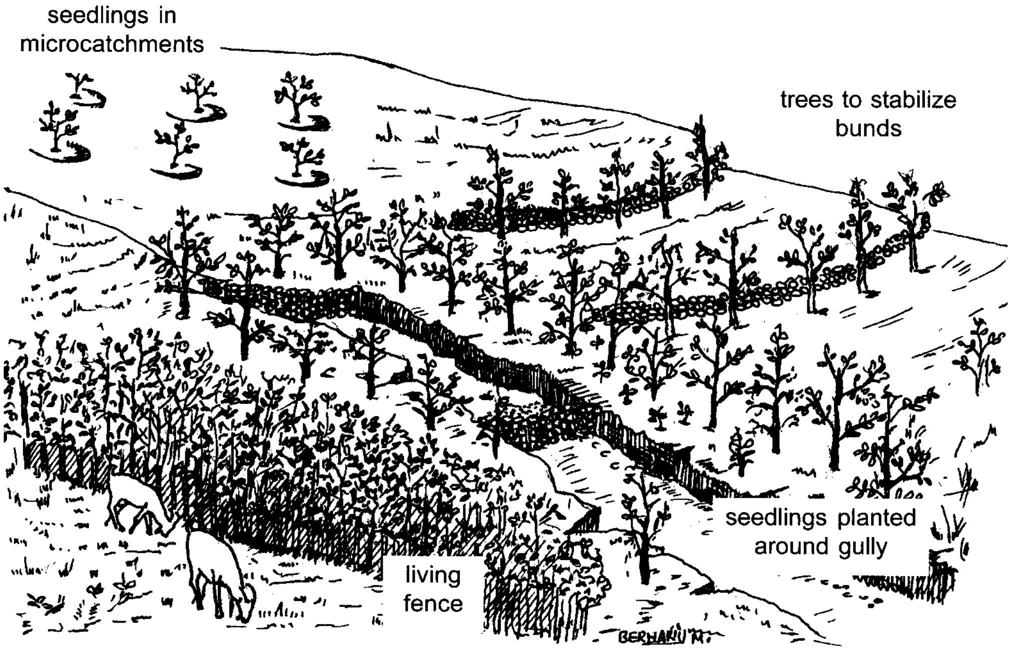
Trees and shrubs can be planted on overused, eroded land to convert it to a forest or woodlot, and make the land fully productive again.

Degraded areas can be closed off to livestock to protect it from grazing and trampling. The vegetation usually recovers quickly, but the particular species that dominates might not be useful. Planting the closed area with trees speeds up the recovery process, and ensures that more desirable tree species grow there (see page 190).

Trees can be planted around the closed area as a live fence. They can also be used to help reclaim gullies (see page 142).

Where to use trees for rehabilitation

Agroclimatic zones All.
Soils Degraded soils.



In the background, seedlings have been planted in microcatchments. To the right, trees are planted to stabilize level bunds. The living fence in the foreground keeps animals away from the gully. Seedlings have been planted around the gully to help prevent further erosion.

Advantages of using trees for rehabilitation

- Trees protect the soil surface from the impact of heavy rainfall. They reduce run-off and prevent erosion.
- Fallen leaves build up organic matter in the soil. Leguminous trees fix nitrogen, increasing the soil fertility.
- Leaves, twigs and pods from trees can be cut and fed to livestock. When the trees have grown and the land has recovered, they can be harvested for wood.

Disadvantages and constraints

- Rehabilitation is a slow process that requires a lot of labour and does not show immediate benefits. (It is important that farmers understand this, so discuss it with them carefully.)
- Closing off the area reduces the amount of land that animals can graze on. (Farmers can still cut grasses and feed them to livestock.)

How to manage trees on degraded land

- Plant trees in spots where there is good soil cover (see page 251). Use microbasins if appropriate (see page 133).
- Prevent gullies from expanding (for example, by building checkdams) before planting trees (see page 142).
- Protect the area from grazing animals. Weed around the trees as required (see page 252).

Woodlots

A woodlot is a group of trees planted and managed to produce timber, poles for house construction, or fuelwood (firewood and charcoal).

For timber and building poles, the aim is to produce tall, straight trunks that do not taper. For firewood and charcoal, the aim is to produce a large amount of wood.

Grevillea robusta and cypress are suitable for timber. *Eucalyptus globulus, E. saligna* and *Acacia decurrens* are often used for building poles and for fuelwood. See Chapter 9 for more species.

Woodlots can be grown by individual farmers or by groups. If the community plans a woodlot, everyone must agree on what land is to be used, who should do the work, and how to share the benefits.

A line of trees can also be used to produce timber, poles or fuelwood. However, freestanding trees will develop very large branches, making them less suitable for use as timber and poles.

Where to grow woodlots

Agroclimatic zones All.
Soils All. Especially useful for less productive land unsuited for crops.

Advantages of woodlots

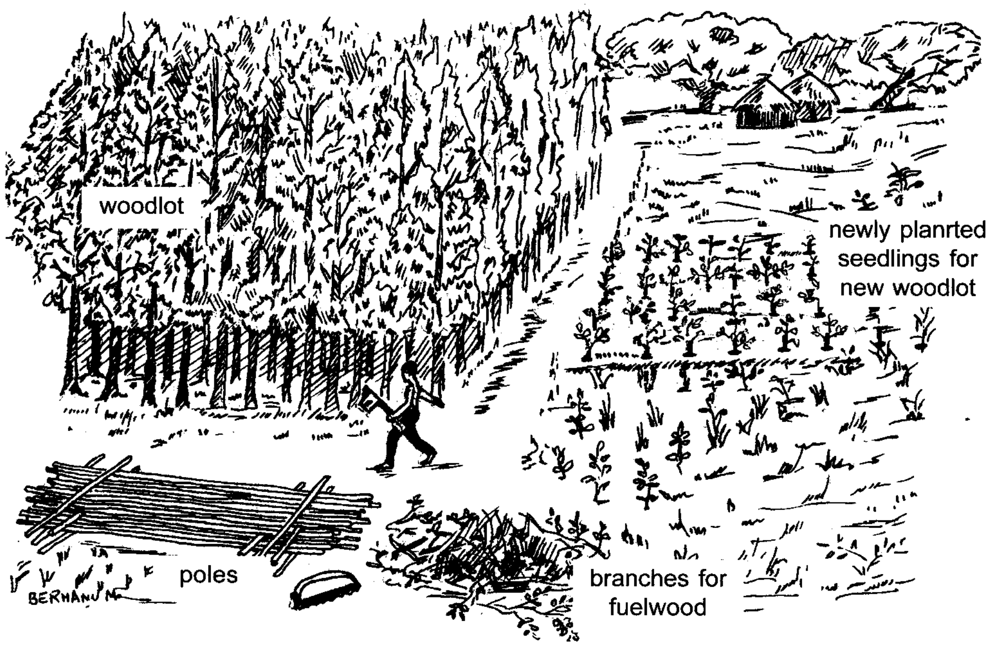
- Woodlots ensure a supply of good-quality timber or building poles or fuel. This is particularly important where farmers have no other source of poles or fuel.
- Producing poles, firewood and charcoal is an easy, good source of income – often producing several times as much income as crops.

Disadvantages and constraints

- Woodlots may take land that could be used for growing crops. (Select land that is not suitable for agriculture.)
- The trees take several years to grow, so farmers might not see an immediate benefit.

Tree spacing

How close together should the trees be planted? This depends on the purpose of the woodlot. Farmers frequently plant the seedlings very close together (1 x 1 m spacing, a density of 10,000 trees per hectare – or even closer). This uses a lot of seedlings, but



A woodlot of densely planted trees used to produce building poles. The farmer can use the trimmed branches as fuel. In a few years, the seedlings in the plot on the right will be a new woodlot.

if a few die, it is not necessary to replace them. The tree canopies shade the ground quickly, so only a little weeding is necessary. Over time, the stand can be thinned (for example, every fourth tree can be cut), producing some wood and giving more space for the remaining trees.

Planting the trees further apart, at a spacing of 2 x 2 m (2500 trees per hectare) or 2.5 x 2.5 m (1600 trees per hectare) uses fewer seedlings, but more weeding is needed. At wider spacings, the individual trees grow larger.

Trees planted in lines can be spaced 0.5 to 1 m apart. They may planted be in a single line, or in two or more lines.

Producing timber

1 Plant the seedlings at a wide spacing (2 x 2 m).
2 Weed regularly, and replace trees that have died about 3–4 months after planting.
3 When the trees are about 5 m tall, prune the lower branches up to a height of 2 m.
4 When the trees are 6–8 years old, when the canopy has closed, thin out the weak or crooked trees. This gives the remaining trees more room to grow.
5 Prune the lower branches of the best remaining trees up to the height of the first log (up to about 4 m high). These trees can be used for good quality timber.
6 Thin again when the trees are 13–15 years old.
7 Harvest the trees when they are mature.

Producing building poles

Eucalyptus is the most common species used for poles. Pruning is not necessary, as the branches fall off naturally. Follow the steps above, except for steps 3 and 5.

The age of harvesting depends on the tree species: typically 8–10 years for eucalyptus and 15–20 years for *Casuarina*, though this depends on the conditions where the trees grow.

For some species, coppicing can produce good-quality poles (see *Coppicing*, page 254).

Producing fuelwood or charcoal

1 Plant the seedlings densely (1 x 1 m).
2 It is not necessary to prune or to remove crooked trees. The trees can be thinned, and the resulting wood sold or made into charcoal.
3 The trees can be harvested when needed – usually earlier than if they are used for building poles. Certain types of trees can be coppiced to produce more wood, avoiding the need to replant (see *Coppicing*, page 254).

Managing trees and shrubs

The following techniques can be used to manage trees and shrubs grown on and around farms, on degraded land, or as woodlots.

Where to manage trees

Agroclimatic zones All.
Soils All.

Advantages of managing trees

- Proper overall management of trees can ensure a continuous supply of wood for building or fuel, as well as fruit, forage and benefits such as shade and fencing.
- It is possible to influence the growth of trees, for example to produce knot-free timber or to encourage fruiting.

Disadvantages and constraints

- Managing trees takes time and effort. Farmers may be unwilling to put in this extra work if they do not see the benefits.

Planting

Plant seedlings at the beginning of the rainy season to give them time to get established while there is still moisture in the soil.

1 Decide where you want to plant the seedlings. If there is dense vegetation, clear an area 1 m around each planting spot. This is especially important in dry areas, as weeds compete with the young trees for moisture.
2 Dig planting holes 30 cm across and 30 cm deep. Digging loosens the soil, allows water to soak into the ground, enables the tree roots to grow easily, and produces an even stand of trees. In very dry areas, microbasins may be necessary to collect water around the young trees (see page 133).
3 When the planting holes are ready, transport the seedlings from the nursery. Handle them carefully to avoid damaging them. The roots are delicate, so protect them from the sun.
4 Do not allow the seedlings to dry out. Plant each seedling as soon as possible. Cover the roots completely with topsoil (mixed with compost if you have some). Compact the soil around the seedling.
5 Protect the seedlings from grazing animals by putting thorn bushes around them, or by fencing the entire area.

Replacement planting

Newly planted seedlings may die if they are handled badly (for example, if the roots are damaged or if they are damaged by livestock). Dead seedlings leave gaps in live fences or windbreaks and must be replaced. It is not normally necessary to replace dead seedlings in a woodlot because of the high planting density – a few gaps do not matter.

If the seedlings are planted early in the season, it may be possible to replace the dead ones with fresh ones in the same season.

1 When planting seedlings, keep a number in reserve in the nursery in case they are needed to replace seedlings that die.
2 Three to four weeks after planting, check the planted area and count the number of dead seedlings that need to be replaced.
3 Remove the dead seedlings and dig new planting holes.
4 Transport the fresh seedlings from the nursery, and plant them in the holes. They should be of the same species as the rest of the plantation.

Weeding

Weeds can easily choke small trees by depriving them of light, water and soil nutrients. Weeds can also help spread fire. Weeding around young trees prevents this.

Weed the area around newly planted trees twice in the first year, before the weeds are able to produce seeds. Use a hoe to clear the weeds from an area 1 m around each tree. If the trees are in rows, remove the weeds 1 m each side of the row. Use the weeds as mulch, or burn them.

Once the trees are 1.5 m tall, it is no longer necessary to weed.

Pruning

Pruning involves cutting off branches from a tree in order to produce knot-free timber or to make the tree a certain shape.

Pruning timber trees

Pruning timber trees when they are young produces wood free of knots, which may fetch a better price than knotty wood.

For timber trees grown in a plantation, prune when the canopy has closed enough to suppress weeds. Prune in the dry season, when there is little risk of fungal diseases.

Cut off all the branches up to a height of 1.5–2 m. Cut the branches cleanly with a sharp saw, as close to the trunk as possible. Avoid tearing the bark on the trunk. Do not remove more than 50% of the foliage, as this will harm the tree's growth. Clear away the pruned branches to reduce the risk of fire.

When the trees are 2–4 years old, they can be pruned up to one-quarter of the height of the tree.

Cypress and *Grevillea robusta* are the only trees commonly grown by farmers for timber that need pruning. Tree that lose their branches naturally, such as eucalyptus, do not need pruning. Pruning is also not necessary for trees intended for other uses (such as fuelwood or land rehabilitation).

Pollarding

Pollarding means cutting off the top of the tree, to force it to grow low and wide. The top branches are also often cut where they join the trunk. Pollarding is widely used in dry areas to increase the amount of fodder available.

Pollarded Grevillea trees grown along the edge of a field (illustration adapted from ICRAF, 1998)

Pruning fruit trees

Most fruit trees require little pruning. But for some trees such as apples, pruning can help increase fruit production and control pests and diseases.

Prune away dead or diseased branches, and branches that are growing straight up or towards the centre of the canopy. Pruning should give the tree the desired shape (for example, to train branches horizontally so the fruit can be picked easily). Removing old branches stimulates the growth of new branches that are more likely to bear fruit. It also improves the amount of light and the circulation of air within the canopy. This reduces the humidity and lowers the risk of fungal diseases.

Prune trees when the tree is dormant. Avoid pruning young trees too severely, because this delays fruiting.

Pruning reduces yields in the short run, but improves the quality and yield of fruit in the years to come.

Thinning

In a woodlot, it is usual to plant more seedlings than will be needed. There are three reasons for this:

- It helps develop a closed canopy quickly, encouraging growth as the seedlings compete for light.
- It avoids the need to replant if some seedlings die.
- It makes it possible to remove any trees that do not grow well.

When the trees are larger, it is necessary to thin out the smaller, weaker trees. This is done to reduce competition among the trees for light, space and nutrients. It allows the remaining trees to grow straight and tall.

How many trees to remove? That depends on the density of the plantation and management considerations.

Removing many trees allows the remaining trees to grow wide and to develop large branches. Too much light may reach the ground, allowing weeds to grow and increasing the risk of fire.

Coppicing

When certain types of trees are cut near the ground, they produce several fresh shoots. These shoots are called 'coppices'. Coppicing avoids the need to replant trees after harvesting, so is a cheap and easy way to renew a plantation. The shoots should be thinned to reduce their number, so that tall, straight trees are produced. Coppicing can also be used to produce firewood and charcoal. *Eucalyptus* and *Casuarina* coppice well. *Juniperus*, *Podocarpus* and many other species do not coppice.

1 Cut the trunk of a mature tree about 10–15 cm from the ground. It is best to use a saw, but if you have only an axe, use it carefully to make sure you get an even cut. Make the cut at a slant to encourage one leading shoot to grow from the top of the stump, and to prevent rainwater from collecting on the top of the stump. Avoid peeling off the bark on the stump.

2 Several shoots will start to grow from the stump. Remove the smaller, weaker shoots when they are about 1 m high, leaving 2–4 longer, straighter ones on each stump.

3 After 4–6 years, the poles will be long enough for use in building. Cut them close to the stump.

4 The stump will again grow new shoots, which you can thin and harvest (see steps 2–3). The coppicing ability of a tree declines gradually as it gets older. Eucalyptus can be coppiced three or four times before it must be replanted.

A coppiced tree. The smaller, weaker shoots should be removed.

Tapping for incense and gum

Certain types of trees in the Kolla and Dry Weyna–Dega zones can be tapped to produce incense (*Boswellia*) or gum Arabic (*Acacia senegal*). Tapping involves making cuts on the trunk so the incense or gum oozes out and can be collected. Farmers generally know how to do this.

The trees are tapped after the end of the rainy season. It can continue until the end of the dry season. Tapping should not be done in the rainy season because of the risk of disease attacking the open cut in the bark.

Young trees should not be tapped. Tapping must be done carefully to avoid killing the trees. Do not cut too deep into the wood, as this harms the tree. After a tree is tapped for about 5 years, it should be left untapped for 2–3 years to allow it to recover.

Bamboo

Bamboo is an important product in the Dega and Weyna–Dega zones. Only the mature stems (2–4 years old) should be harvested. Their leaves have spots, and the stems are thick and yellow. They are generally found in the centre of a clump of bamboo. Leave the younger stems to grow. Cutting is done during the dry season because the stems will be dry and woody then.

Reforestation in Illubabor

Most of the forest cover in Bure woreda, Illubabor Zone, had been destroyed, but farmers were not interested in planting trees because they did not see the immediate benefits. They resisted attempts to persuade them to do so.

Then extension staff from the NGO Menschen für Menschen noticed that farmers would travel for up to 2 days to fetch wild coffee seedlings from remote areas. They brought these seedlings home and planted them in their backyards.

The extension workers saw an opportunity to improve the coffee production and to promote tree planting at the same time. Coffee needs shade, so they introduced shade trees in the backyards. They also introduced multistorey agroforestry, using coffee interplanted with avocado, papaya, dwarf Cavendish banana, and spices.

To qualify for seedlings, farmers had to plant shade trees and build soil conservation structures. About 2400 farmers have joined this programme, and the results have been impressive. A large area of bare land has been rehabilitated, and the farmers are better off. Many now have replaced their thatched roofs with corrugated sheets – a sure sign of greater wealth.

9

Agroclimatic suitability of forage, trees, shrubs and crops

This chapter lists the major species of forage, trees and shrubs, field crops and horticultural crops in Ethiopia.

- A **solid bullet** (•) shows that a species is generally suited to that agroclimatic zone.
- A **cross** (x) means it is suited to part of the zone.

The species may grow outside of these areas, but may not grow or yield well.

Forages

Botanical name	English	Alpine Wurch	Moist Wurch	Wet Wurch	Dry Dega	Moist Dega	Wet Dega	Dry Weyna-Dega	Moist Weyna-Dega	Wet Weyna-Dega	Dry Kolla	Moist Kolla	Wet Kolla	Dry Bereha	Moist Bereha
Altitude (m)		> 3700	3200–3700			2300–3200			1500–2300			500–1500			< 500
Rainfall (mm)		900–1400	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400
Grasses															
Andropogon gayanus							•								
Avena sativa	Oats				•	•	•								
Cenchrus ciliaris	Buffel grass							•	•		•	•			
Chloris gayana	Rhodes grass							•	•		•	•			
Dactylis glomerata	Cocksfoot				•	•									
Danthonia sp.				•	•										
Festuca arundinacea	Tall fescue				•	•									
Harpachne schimperi									•	•					
Hyparrhenia spp.									•	•					
Panicum maximum	Guinea grass Gatton panic, green panic							•	•		•	•			
Pennisetum purpureum	Elephant grass, Napier					•			•	•		•			
Phalaris aquatica	Phalaris					•	•		•	•					
Poa spp.			•	•		•									

Forages (continued)

Botanical name	English	Alpine Wurch	Moist Wurch	Wet Wurch	Dry Dega	Moist Dega	Wet Dega	Dry Weyna-Dega	Moist Weyna-Dega	Wet Weyna-Dega	Dry Kolla	Moist Kolla	Wet Kolla	Dry Bereha	Moist Bereha
Altitude (m)		> 3700	3200–3700		2300–3200			1500–2300			500–1500			< 500	
Rainfall (mm)		900–1400	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400
Stylosanthes hamata	Caribbean stylo, verano							•			•				
Stylosanthes scabra	Shrubby stylo, seca							•			•				
Trifolium repens	White clover		•	•		•	•			•					
Vicia varia	Vetch					•	•	•	•	•	•		•		
Vigna unguiculata	Cowpea								•			•			
Root crops															
Beta vulgaris	Fodder beet				•	•	•	•	•						
Succulents															
Atriplex nummularia	Oldman saltbrush							•			•	•			
Opuntia ficus-indica	Spineless cactus										•	•			

Trees and shrubs

Botanical name	English	Alpine Wurch	Moist Wurch	Wet Wurch	Dry Dega	Moist Dega	Wet Dega	Dry Weyna-Dega	Moist Weyna-Dega	Wet Weyna-Dega	Dry Kolla	Moist Kolla	Wet Kolla	Dry Bereha	Moist Bereha
Altitude (m)		> 3700	3200–3700		2300–3200			1500–2300			500–1500			< 500	
Rainfall (mm)		900–1400	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400
Acacia spp.	Acacia					•	•	•	•	•	•	•			
Adhatoda sp.								•	•						
Ailanthus glandulosa											•	•			
Albizia spp.	Albizia							•		•	•	•			
Apodytes dimidiata	White pear, pearwood						•								
Azadirachta indica	Neem										•				
Balanites aegyptiaca	Desert date							•			•	•			
Cajanus cajan	Pigeonpea							•	•		•	•			
Calliandra calothyrsus	Calliandra								•	•		•	•		•
Cassia sp.	Cassia								•						
Casuarina equisetifolia	Casuarina							•				•			
Casuarina cunninghamiana								•				•			
Celtis africana						•			•	•					
Chamaecytisus palmensis	Tree lucerne		•	•	•	•			•						
Conocarpus lancifolius											•				

Trees and shrubs (continued)

Botanical name	English	Alpine Wurch	Moist Wurch	Wet Wurch	Dry Dega	Moist Dega	Wet Dega	Dry Weyna-Dega	Moist Weyna-Dega	Wet Weyna-Dega	Dry Kolla	Moist Kolla	Wet Kolla	Dry Bereha	Moist Bereha
Altitude (m)		> 3700	3200–3700			2300–3200			1500–2300			500–1500			< 500
Rainfall (mm)		900–1400	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400
Cordia africana					•	•	•	•	•	•					
Croton macrostachyus							•		•	•					
Cupressus lusitanica	Mexican cypress		•	•		•	•		•	•					
Ekebergia capensis									•						
Erica arborea	Giant heath		•	•											
Erythrina abyssinica	Flame tree						•		•	•					
Eucalyptus viminalis	Eucalyptus		×	×											
Euphorbia spp.	Euphorbia					•	•	•	•						
Ficus spp.									•	•					
Gliricidia spp.	Gliricidia										•	•	•		•
Grevillea robusta	Silky oak								•	•					
Hagenia abyssinica			×	×		•	•								
Hypericum spp.			•	•											
Juniperus procera	African pencil cedar		•			•	•	•	•	•					

Trees and shrubs (continued)

Botanical name	English	Alpine Wurch	Moist Wurch	Wet Wurch	Dry Dega	Moist Dega	Wet Dega	Dry Weyna-Dega	Moist Weyna-Dega	Wet Weyna-Dega	Dry Kolla	Moist Kolla	Wet Kolla	Dry Bereha	Moist Bereha
Altitude (m)		> 3700	3200–3700		2300–3200			1500–2300			500–1500			< 500	
Rainfall (mm)		900–1400	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400
Leucaena leucocephala	Leucaena							•			•				
Maesa lanceolata						•									
Maytenus spp.						•	•								
Moringa oleifera	Horseradish tree										•	•			
Nuxia congesta						•	•								
Olea europaea ssp *africana*	East African olive					•	•	•	•	•					
Parkinsonia aculeata	Jerusalem thorn										•	•			
Pinus patula	Pine					•	•			•		x			
Pinus radiata	Pine					•	•			•		x			
Podocarpus falcatus	Podo								•	•					
Polyscias fulva										•					
Prosopis juliflora	Mesquite							•			•				
Prunus africana	Pygeum						•			•					
Schinus molle	Pepper tree		•			•		•	•		•	•			
Sesbania sesban	Sesbania				•			•				•			

Trees and shrubs (continued)

Botanical name	English	Alpine Wurch	Moist Wurch	Wet Wurch	Dry Dega	Moist Dega	Wet Dega	Dry Weyna-Dega	Moist Weyna-Dega	Wet Weyna-Dega	Dry Kolla	Moist Kolla	Wet Kolla	Dry Bereha	Moist Bereha
Altitude (m)		> 3700	3200–3700			2300–3200			1500–2300			500–1500			< 500
Rainfall (mm)		900–1400	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400
Syzygium guineense	Waterberry					•									
Tamarix aphylla	Tamarisk										•				
Ziziphus pubescens											•	•			•
Ziziphus spina-christi											•	•			

Field crops

Botanical name	English	Alpine Wurch	Moist Wurch	Wet Wurch	Dry Dega	Moist Dega	Wet Dega	Dry Weyna-Dega	Moist Weyna-Dega	Wet Weyna-Dega	Dry Kolla	Moist Kolla	Wet Kolla	Dry Bereha	Moist Bereha
Altitude (m)		> 3700	3200–3700		2300–3200			1500–2300			500–1500			< 500	
Rainfall (mm)		900–1400	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400
Arachis hypogaea	Groundnut				•	•	•		•	•					
Avena sativa	Oats		•	•	•	•	•	•	•	•					
Brassica napus	Rapeseed							•	•	•					
Carthamus tinctorius	Safflower									•	•	•			
Eleusine coracana	Finger millet							•	•	•	•	•	•		
Ensete ventricosum	Enset		•	•	•	•	•	•	•	•			•		
Eragrostis tef	Tef							•	•	•	•	•	•		
Glycine max	Soybean									•	•	•	•		
Guizotia abyssinica	Niger seed, *nug*					•	•	•	•	•					
Hordeum vulgare	Barley		•	•	•	•	•		•	•					
Ipomoea batatas	Sweet potato							•	•	•	•	•	•		
Lens esculenta	Lentils					•	•	•	•	•			•		
Linum usitatissimum	Linseed				•	•	•	•	•	•					
Lupinus sp.	Lupin								•	•					
Pennisetum glaucum	Pearl millet								•	•					

Field crops (continued)

Botanical name	English	Alpine Wurch	Moist Wurch	Wet Wurch	Dry Dega	Moist Dega	Wet Dega	Dry Weyna-Dega	Moist Weyna-Dega	Wet Weyna-Dega	Dry Kolla	Moist Kolla	Wet Kolla	Dry Bereha	Moist Bereha
Altitude (m)		> 3700	3200–3700			2300–3200			1500–2300			500–1500			< 500
Rainfall (mm)		900–1400	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400
Phaseolus aureus	Mungbean									•	•	•			
Pisum sativa	Field pea		•	•	•	•	•	•	•	•					
Secale cereale	Rye														
Sesamum indicum	Sesame										•	•	•		
Solanum tuberosum	Potato		•	•	•	•	•	•	•	•					
Sorghum bicolor	Sorghum							•	•	•	•	•	•		
Trigonella foenum-graecum	Fenugreek		•	•	•	•	•	•	•	•					
Triticum aestivum	Wheat					•	•	•	•	•					
Vicia faba	Faba bean, horsebean				•	•	•	•	•	•					
Vigna unguiculata	Cowpea							•			•				
Zea mays	Maize				•	•		•	•	•	•	•	•		

Horticultural crops

Botanical name	English	Alpine Wurch	Moist Wurch	Wet Wurch	Dry Dega	Moist Dega	Wet Dega	Dry Weyna-Dega	Moist Weyna-Dega	Wet Weyna-Dega	Dry Kolla	Moist Kolla	Wet Kolla	Dry Bereha	Moist Bereha
Altitude (m)		> 3700	3200–3700		2300–3200			1500–2300			500–1500			< 500	
Rainfall (mm)		900–1400	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400
Allium cepa	Onion		•		•	•	•		•	•		•	•		
Ananas comosus	Pineapple					•		•	•	•		•	•		
Annona senegalensis	Annona														
Beta vulgaris	Sugar beet								•	•		•	•		
Brassica carinata	*Yabasha-gomen*, Ethiopian cabbage					•			•	•		•	•		
Brassica juncea	Mustard								•	•		•	•		
Brassica oleracea	Cabbage								•	•		•	•		
Camellia sinensis	Tea										•	•	•		
Catha edulis	Chat								•	•		•	•		
Citrullus lanatus	Watermelon														
Citrus limon	Lemon				•	•		•	•	•		•	•		
Citrus medica	Citron					•	•			•			•		
Citrus reticulata	Mandarin					•		•	•	•		•	•		

Horticultural crops (continued)

Botanical name	English	Alpine Wurch	Moist Wurch	Wet Wurch	Dry Dega	Moist Dega	Wet Dega	Dry Weyna-Dega	Moist Weyna-Dega	Wet Weyna-Dega	Dry Kolla	Moist Kolla	Wet Kolla	Dry Bereha	Moist Bereha
Altitude (m)		> 3700	3200–3700		2300–3200			1500–2300			500–1500			< 500	
Rainfall (mm)		900–1400	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400	>1400	<900	900–1400
Citrus sinensis	Orange				•	•		•	•	•		•	•		
Citrus paradisi	Grapefruit					•			•	•			•		
Coffea arabica	Coffee					•			•	•			•		
Daucus carota	Carrot				•	•	•	•	•	•		•	•		
Gossypium hirsutum	Cotton							•				•	•		•
Lagenaria siceraria	Calabash					•	•		•	•		•	•		
Lycopersicon esculentum	Tomato					•	•	•	•	•		•	•		
Malus domestica	Apple		•			•	•		•	•					
Mangifera indica	Mango					•		•	•	•	•	•	•		
Musa spp.	Banana								•	•		•	•		
Phaseolus vulgaris	Haricot bean														
Prunus persica	Peach					•	•		•	•			•		
Prunus domestica	Plum		•		•	•	•	•	•	•					
Saccharum officinarum	Sugarcane							•	•	•	•	•	•		

10
Appendices

Writeshop participants

Main authors

The authors prepared draft manuscripts, presented them to the writeshop, and followed their production to the final stage.

- **Azene Bekele-Tesemma**, development specialist, capacity building, RELMA in ICRAF, Nairobi, Kenya
- **Berhanu Fentaw**, land and water management specialist, Ministry of Agriculture and Rural Development
- **Gashaw Geda**, head, Curriculum Development and Programme Supervision Team, Ministry of Agriculture and Rural Development
- **Getachew Felleke**, livestock production and dairy specialist, Ministry of Agriculture and Rural Development
- **Habtamu Gessesse**, country representative, Water Aid
- **Håkan Sjöholm**, forestry specialist, Bromma, Sweden
- **Hune Nega**, senior soil and water conservation expert, Agricultural Extension Department, Ministry of Agriculture and Rural Development
- **Million Bekele**, team leader, forestry sector, Natural Resources Department, Ministry of Agriculture and Rural Development
- **Shelemew W/Mariam**, senior agronomist, Crop Production Department, Ministry of Agriculture and Rural Development

Reviewers and resource persons

The reviewers participated in the writeshop as subject specialists or potential users of the book. They reviewed the manuscripts and illustrations, and suggested corrections and improvements. They also helped develop new text during the writeshop.

- **Aichi Kitalyi**, development specialist, livestock and land intensification, RELMA in ICRAF, Nairobi, Kenya
- **Aliye Huseen**, development agent, Ministry of Agriculture and Rural Development, Negelleeborena
- **Ayalew Teshome**, development agent, Ministry of Agriculture and Rural Development

- **Ayena Adrena Gebru**, development agent, Bureau of Agriculture and Rural Development, Gibrina, Atsbi Weberta, Tigray
- **Berhe W/Aregay**, freelance consultant, Addis Ababa
- **Dejene Abesha**, team leader, water resource, Ministry of Agriculture and Rural Development, Addis Ababa
- **Desalegn Maru**, development agent, Ministry of Agriculture and Rural Development
- **Fiker Bayalie**, development agent, Ministry of Agriculture and Rural Development, Debark
- **Genet Tamiru**, development agent, Ministry of Agriculture and Rural Development, Alaba
- **Kedir Ibrahim**, Instruction Curriculum Development and Research (ICDR), MOE, Addis Ababa
- **Melesse Temesgen**, Ethiopia Agricultural Research Organization, Nazareth
- **Nigussie Tefera**, development agent, Ministry of Agriculture and Rural Development, Shoarobit
- **Siyum Tedla**, development agent, Ministry of Agriculture and Rural Development, Samre
- **Tadesse Fekensa**, development agent, Ministry of Agriculture and Rural Development
- **Tarikua Elias**, development agent, Ministry of Agriculture and Rural Development, Alaba
- **Teketel Awol**, extension agent, Ministry of Agriculture and Rural Development, Alaba
- **Tesfaye Haile**, development agent, Ministry of Agriculture and Rural Development, Robe
- **Tessema Teklu**, woreda soil conservation and agroforestry team leader, Ministry of Agriculture and Rural Development, Wolkite
- **Teweldebrhan G/Kidan**, departmental head for agroecology, Menschen für Menschen, Merhabaete, Alem Ketema
- **Tsadik Hagos**, development agent, Ministry of Agriculture and Rural Development, Wachile
- **Yohannes Wasihun**, development agent, Ministry of Agriculture and Rural Development, Dangila
- **Yoseph Ayalew**, supervisor, Agri-Service Ethiopia, Mertulemariam

Production

The production team planned and managed the writeshop process, and worked on the final draft of the book afterwards. They also helped develop some new text.

- **Anna Karlsson-Lindqvist**, development specialist, information and communication, RELMA in ICRAF, Nairobi, Kenya
- **Anne-Marie Nyamu**, freelance editor, Nairobi, Kenya
- **Berhanu Mekonnen**, freelance artist, Addis Ababa
- **Bob Wagner**, editor, Nairobi, Kenya
- **Isaac Bekalo**, director, IIRR Africa, Nairobi, Kenya
- **Janet Munyasya**, development communication assistant, RELMA in ICRAF, Nairobi, Kenya
- **Kiddest Bereket**, administrator, IIRR Ethiopia
- **Kimunya Mugo**, development communication officer, RELMA in ICRAF, Nairobi, Kenya
- **Kithinji Kiruja**, design consultant, Nairobi, Kenya
- **Lealem Berhanu**, country programme coordinator, IIRR – Ethiopia
- **Meheret Garuma**, secretary, IIRR Ethiopia
- **Paul Mundy**, development communication specialist, Bergisch Gladbach, Germany
- **Sospeter Gatobu**, communication specialist, IIRR Africa, Nairobi, Kenya
- **Yetagesu Mergia**, freelance artist, Addis Ababa

References for further reading

Bekele-Tesemma, Azene, Birnie, A., and Tengnäs, A. 1993. *Useful trees and shrubs of Ethiopia*. Technical handbook No. 5. Regional Land Management Unit (RELMA), Nairobi.

Bekele-Tesemma, Azene. 1997. A participatory agroforestry approach for soil and water conservation in Ethiopia. *Tropical Resources Management Papers* 17, Wageningen Agricultural University, Netherlands.

Brännäng, E. and Persson S. 1990. *Ethiopian animal husbandry: A handbook*. Swedish University of Agricultural Sciences, Uppsala, Sweden.

Brouwer, C., Goffeau, A. and Heibloem, M. 1985. *Irrigation water management: Introduction to irrigation*. Irrigation water management training manual No. 1. Food and Agriculture Organization of the United Nations, Rome. www.fao.org/docrep/R4082E/r4082e00.htm

Brouwer, C., and Prins, K. 1989. *Irrigation water management: Irrigation scheduling*. Irrigation water management training manual No. 4. Food and Agriculture Organization of the United Nations, Rome. www.fao.org/docrep/T7202E/t7202e00.htm

Brouwer, C., Prins, K., Kay, M., and Heibloem, M. 1990. *Irrigation water management: Irrigation methods*. Irrigation water management training manual No. 5. Food and Agriculture Organization of the United Nations, Rome. www.fao.org/docrep/S8684E/s8684e00.htm

Critchley, W., and Siegert, K. 1991. *Water harvesting: A manual for the design and construction of water harvesting schemes for plant production*. Food and Agriculture Organization of the United Nations, Rome. www.fao.org/docrep/u3160e/u3160e00.htm

Danano, D. (ed.). In press. *Soil and water conservation manual: Guidelines for Ethiopia*. Natural Resources Management and Regulatory Department, Ministry of Agriculture, Addis Ababa.

Evans, Julian. 1992. *Plantation forestry in the tropics: Tree planting for industrial, social, environmental, and agroforestry purposes*. 2nd ed. Clarendon Press, Oxford.

FAO. 1983. *Fertilizer use under multiple cropping systems*. Fertilizer and plant nutrition bulletin, No. 5. Food and Agricultural Organization of the United Nations, Rome.

GTZ. 1996. *Ethiopian forestry manual for professional and sub-professional field staff.* Forestry and Wildlife Conservation and Development Team and German Technical Cooperation (GTZ) Forestry Project, Ministry of Agriculture, Addis Ababa.

Hai, M.T. 1998. *Water harvesting: An illustrative manual for development of microcatchment techniques for crop production in dry areas.* Technical handbook No. 16. Regional Land Management Unit (RELMA), Nairobi.

ICRAF. 1988. *Agroforestry in dryland Africa.* International Centre for Research in Agroforestry, Nairobi.

IIRR. 1998. *Sustainable agriculture extension manual for eastern and southern Africa.* International Institute of Rural Reconstruction, Nairobi.

IIRR. 2002. *Managing drylands: A manual for eastern and southern Africa.* International Institute of Rural Reconstruction, Nairobi.

IIRR, Cordaid and Acacia Consultants. 2004. *Drought cycle management: A toolkit for the drylands of the Greater Horn of Africa.* International Institute of Rural Reconstruction, Nairobi; Cordaid, The Hague; and Acacia Consultants, Nairobi.

Jeavons, J., and Cox, C. 2002. *The sustainable vegetable garden: A backyard guide to healthy soil and higher yields.* Ten Speed Press, Berkeley, California.

Jonfa, Ejigu, and Pound, B. (eds). 2002. *Farmer participatory research and extension guideline.* Farm Africa and Institute for Sustainable Development, Addis Ababa.

Mathewman, R.W. 1993. *Dairying.* Tropical Agriculturalist Series. Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen, Netherlands, and Macmillan, London.

Mengistu, Aiemayehu. 1997. *Conservation-based forage development for Ethiopia.* Self-help Development International Institute for Sustainable Development, Addis Ababa.

Mengistu, Aiemayehu. 2002. *Forage production in Ethiopia: A case study with implications for livestock production.* Ethiopian Society of Animal Production, Addis Ababa.

Ministry of Agriculture. 1986. *Guidebook for development agents on soil conservation in Ethiopia.* Community Forests and Soil Conservation Development Department, Ministry of Agriculture, Addis Ababa.

Ministry of Agriculture. 1989. *Guidebook for development agents on community forestry in Ethiopia.* Community Forests and Soil Conservation Development Department, Ministry of Agriculture, Addis Ababa.

Ministry of Agriculture. 1990. *Feed development and utilization manual.* (in Amharic). Fourth Livestock Development Project, Animal and Fisheries Resources Development Department, Ministry of Agriculture, Addis Ababa.

Ministry of Agriculture. 1990. *Forage development extension manual.* Animal and Fisheries Resources Development Department, Ministry of Agriculture, Addis Ababa.

Ministry of Agriculture. 1990. *Forage seed production extension manual.* Animal and Fisheries Resources Development Department, Ministry of Agriculture, Addis Ababa.

Ministry of Agriculture. 2002. *Gender and food security in Ethiopia: Constraints and opportunities.* Women's Affairs Department, Ministry of Agriculture, Addis Ababa.

Ministry of Agriculture. 2002. *Rainwater harvesting extension manual* (Amharic version). Ministry of Agriculture, Addis Ababa.

Miteku, Asefa, and Sisay, Kebede. 1991. *Compost-making for farmers: Using organic matter to prepare fertilizer* (in Amharic). Agriservice-Ethiopia. Addis Ababa.

Nega, Hune, and Kimeu, P.M. 2002. *Low-cost methods of rainwater storage: Results from field trials in Ethiopia and Kenya.* Technical report No. 28. Regional Land Management Unit (RELMA), Nairobi.

Nissen-Petersen, E., and Lee, M. (1990) *Harvesting rainwater in semi-arid Africa. Manual no. 1: Water tanks with guttering and handpump.* ASAL, Nairobi.

Sastry, N.S.R., Thomas, C.K. and Singh, R.A. 1982. *Farm animal management and poultry production.* 2nd revised version. Vikas Publishing House, Calcutta.

Oweis, T., Prinz, D., and Hachum, A. 2001. *Water harvesting: Indigenous knowledge for the future of the drier environments.* International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria

Thomas, D.B. (ed). 1997. *Soil and water conservation manual for Kenya.* Soil and Water Conservation Branch, Ministry of Agriculture, Livestock Development and Marketing, Nairobi.

11
Index

Botanical names and non-English words are in *italics*. Cross-references to other terms in the index are in SMALL CAPITALS. Major references are in **boldface**.

A

B

C

D

E

J

K

L

M

N

O

P

R

S

T

U

V

W

X

Y

Z

Technical handbook (TH) series

Useful trees and shrubs for Kenya
Patrick Maundu and Bo Tengnäs (eds), Nicholas Muema and Ann Birnie (principal ill). 2005. TH No. 35. ISBN 9966-896-70-8

Fruits and nuts: species with potential for Tanzania
Agnes Nyambo, Agnes Nyamoro, Christoffer Ruffo and Bo Tengnäs. 2005. TH No. 34. ISBN 9966-896-71-6

More forage, more milk
Aichi Kitalyi, David M. Miano, Sandra Mwebaze and Charles Wambugu. 2005. TH No. 33. ISBN 9966-896-74-0

Water from ponds, pans and dams: a manual on planning, design, construction and maintenance
2005. TH No. 32. ISBN 9966-896-67-8

Agroforestry handbook for the montane zone of Uganda
Alex Lwakuba, Alice A. Kaudia and John Okorio. 2003. TH No. 31. ISBN 9966-896-55-4

Soil fertility and land productivity
Charles K.K. Gachene and Gathiru Kimaru. 2003. TH No. 30. ISBN 9966-896-66-X

Soil and water conservation manual for Eritrea
Amanuel Negassi, Estifanos Bein, Kifle Ghebru and Bo Tengnäs. 2002. TH No. 29. ISBN 9966-896-65-1

Management of Rangelands: Use of natural grazing resources in Southern Province, Zambia
Evaristo C. Chileshe and Aichi Kitalyi. 2002. TH No. 28. ISBN 9966-896-61-9

Edible wild plants of Tanzania
Christopher K. Ruffo, Ann Birnie and Bo Tengnäs. 2002. TH No. 27. ISBN 9966-896-62-7

Tree nursery manual for Eritrea
Chris Palzer. 2002. TH No. 26. ISBN 9966-896-60-0

ULAMP extension approach: a guide for field extension agents
Anthony Nyakuni, Gedion Shone and Arne Eriksson. 2001. TH No. 25. ISBN 9966-896-57-0

Drip Irrigation: options for smallholder farmers in eastern and southern Africa
Isaya V. Sijali. 2001. TH No. 24. ISBN 9966-896-77-5

Water from sand rivers: a manual on site survey, design, construction, and maintenance of seven types of water structures in riverbeds
Erik Nissen-Petersen. 2000. TH No. 23. ISBN 9966-896-53-8

Rainwater harvesting for natural resources management: a planning guide for Tanzania
Nuhu Hatibu and Henry F. Mahoo (eds.). 2000. TH No. 22. ISBN 9966-896-52-X

Agroforestry handbook for the banana-coffee zone of Uganda: farmers' practices and experiences
I. Oluka-Akileng, J. Francis Esegu, Alice Kaudia and Alex Lwakuba. 2000. TH No. 21. ISBN 9966-896-51-1

Land resources management: a guide for extension workers in Uganda
Charles Rusoke, Anthony Nyakuni, Sandra Mwebaze, John Okorio, Frank Akena and Gathiru Kimaru. 2000. TH No. 20. ISBN 9966-896-44-9

Depleted soils, erosion, water shortage, lack of animal feed these are familiar problems for Ethiopia's farmers. This richly illustrated practical guide shows how to overcome them. It shows how to improve soil fertility, prevent erosion and store precious water, manage fodder and livestock, and plant and care for trees and shrubs.

Ethiopia is a diverse country, so the most appropriate technology depends on local circumstances. The book shows what technologies can be used in each of the country's major agroclimatic zones. It also suggests how to organize farmers and help them make their own informed decisions to improve their farm incomes.

This book is intended for development agents, but it will also be invaluable for government officials, development agencies, NGO staff, students, and all those promoting sustainable land management in Ethiopia.

ISBN 9966-896-69-4

Ministry of Agriculture and Rural Development, Ethiopia

RELMA

World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

Ministry of Agriculture and Rural Development, Federal Democratic Republic of Ethiopia
P.O. Box 62347, Addis Ababa, Ethiopia, Tel: (+251) 01-518040

World Agroforestry Centre—Eastern and Central Africa's Regional Land Management Unit (RELMA in ICRAF)
P. O. Box 30677-00100, Nairobi, Kenya, Tel: (+254 20) 722 4000, Fax: (+254 20) 722 4001, E-mail: relma@cgiar.org
www.relma.org, www.worldagroforestry.org