TECHNICAL HANDBOOK No. 7

SOIL CONSERVATION IN ARUSHA REGION, TANZANIA

Manual for Extension Workers with Emphasis on Small-Scale Farmers

Per Assmo
with Arne Eriksson

Ministry of Agriculture, Tanzania
Soil Conservation and Agroforestry Project Arusha
(SCAPA)

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Per Assmo with Arne Eriksson
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Soil Conservation in Arusha Region, Tanzania

Per Assmo
with
Arne Eriksson

Regional Soil Conservation Unit
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PUBLISHER'S PREFACE

The Soil Conservation and Agroforestry Project–Arusha (SCAPA) was launched in the late 1980s as a pilot project of SIDA's Regional Soil Conservation Unit (RSCU) in Nairobi. Activities started in 1989 in Arumeru District with trials and demonstrations in selected locations. At the same time staff was trained in basic soil conservation techniques and sent to Kenya on study visits. Thus, SCAPA initially benefited from the soil conservation experiences in Kenya. The aim was to adapt and put into practice production-oriented conservation measures relevant for the smallholder conditions in Arumeru. However, over the years, SCAPA has evolved in its own direction and has now an independent profile. Its extension approach is to facilitate agricultural, forestry and animal husbandry experts and extension workers to work together and develop integrated extension packages in which conservation and increased production go hand in hand. SCAPA now reaches some 4,500 farm households.

SCAPA was administered by RSCU during1988–1993 whereafter it was included in the bilateral development co-operation programme between the Governments of Tanzania and Sweden.

RSCU has supported staff development and technical interventions in Arumeru District through SCAPA. In 1993, the idea was floated to summarize the experience gained in a technical manual which could be of use both in Arusha and in other regions with similar agro-ecological conditions. The manual evolved during a number of workshops held in 1993/94.

We hope that this manual will be of practical use for extension workers in many parts of Tanzania.

Dr Michael Ståhl
Head, Regional Soil Conservation Unit
Nairobi, June, 1994

FOREWORD

The Soil Conservation and Agroforestry Project Arusha (SCAPA) operates in Arusha Region, Tanzania. The project is essentially a training programme to benefit extension workers and farmers. SCAPA also implements practical soil conservation and agroforestry activities in Arumeru and Arusha districts. SCAPA was established in February 1989 by the Swedish International Development Authority (SIDA) through its Regional Soil Conservation Unit (RSCU). The project is implemented through the Regional Development Director (RDD) in Arusha Region.

The project is not strictly connected to one technical department but instead operates as an integrated project. The Project Co-ordininator is the team leader of the Project Co-ordinating Team (PCT) which includes personnel from various disciplines or departments. The Project Co-ordinator is answerable to the District and Regional Soil Conservation Committees and the Ministry of Agriculture.

SCAPA has developed an integrated approach to soil conservation and agroforestry, working with farmers' active participation in planning, implementation and maintenance of conservation activities. The project utilizes simple and appropriate techniques and equipment which are within the reach of farmers and extension workers. The PCT organizes and assists farmers to elect Soil Conservation Committees (SCC) in their respective villages/catchments. The committees are responsible for co-ordinating and implementing soil conservation activities in their villages/catchments.

The soil conservation manual

Training of various target groups is the most important component of SCAPA. So far, most soil conservation training and extension materials used by the project originate from Kenya and consequently refer to Kenyan conditions. There was therefore a need to compile a manual on soil conservation methods and techniques suitable for Tanzania. This manual provides extension staff and farmers with basic knowledge on the integration of soil conservation in farm management. Although the manual has been developed by SCAPA in Arusha Region, we believe that it can also be useful and utilized in other parts of Tanzania.

Per Assmo and Arne Eriksson

ACKNOWLEDGEMENTS

This manual is based mainly on ideas derived from personnel within the Soil Conservation and Agroforestry Project Arusha (SCAPA) and resource persons in Arusha Region. It is to a large extent a result of the practical experience gained from the implementation of SCAPA. Many other sources have also provided information and ideas, and numerous text books, reports and training papers have been consulted.

Credit is given to the authors and publisher of the book, *Useful Trees and Shrubs for Tanzania*, published by the Regional Soil Conservation Unit, SIDA, Nairobi, 1994, from where the material found in Appendix 1 is derived. Appreciation is also given to Mr Terry Hirst, artist and publisher, for allowing us to use pictures from the book, *Agroforestry in Dryland Africa*, published by the International Council for Research in Agroforestry, Nairobi,1988. The information in Appendix 2 is from the book, *Tropical Grasses*, by P.J. Skerman and F. Riveros, Food and Agriculture Organization of the United Nations, Rome, 1990.

The material for the manual was compiled by a team of resource persons during three workshops conducted in Arusha. The team consisted of people from different disciplines who are practically involved in training and implementation of soil conservation activities. My sincere thanks go to the resource team:

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Mr G. Urio	Soil Conservation Officer (SCAPA)

Appreciation is given to the Swedish International Development Authority (SIDA) and its Regional Soil Conservation Unit (RSCU) in Nairobi for funding and technical support to SCAPA and this manual. Special thanks go to the specialists at RSCU, Dr Michael Ståhl, Mr Paul Rimmerfors, Mr Aldo de Kartzow, Mr Björn Hansson and Mr Åke Lennartson for their ideas, recommendations and assistance in the production of this manual. I also wish to express my sincere gratitude to Mr Bo Tengnäs, formerly working with RSCU, for his vital contribution in reviewing parts of the draft.

Per Assmo
Arusha, May, 1994

1

INTRODUCTION

1.1 Soil conservation in Tanzania

Land degradation is one of the major threats to agricultural development in Tanzania. With a fast growing population largely dependent on agriculture for its income and subsistence, soil conservation aimed at an increase in agricultural production on a sustainable basis ought to be given priority.

Soil conservation is not new to Tanzania. Traditional soil conservation systems have existed long before the colonial powers imposed new models. Unfortunately, most colonial efforts to conserve the soil were not successful. Partly developed in other countries under different physical/socio-economic conditions, they were introduced and imposed by the colonial administration without acceptance by the rural communities. Soil conservation as a concept had, in many areas, a bad reputation as it usually meant restrictions and regulations on traditional farming and grazing practices.

It took some years after independence before the need for soil conservation measures was officially recognized and accepted by the Tanzanian authorities. Unfortunately, this new concern, which came in the late 1960s and early 1970s, mainly resulted in surveys of natural resources instead of practical implementation at village level. There was also a misconception at policy-making level that soil conservation in the context of local farming systems requires capital-intensive measures based on machinery earlier introduced by the colonial administration. A number of area-based projects were started, but very few were successful.

During the 1970s and early 1980s the general understanding on how to promote and implement soil conservation activities on farm land in traditional African farming systems improved. The approach included training of local farmers so they could understand the problems of soil erosion and learn how to implement and sustain soil conservation measures on their farms. Even with this approach, achievements were limited. One of the major reasons for the limited success was that soil conservation was taken into specific technical departments without any integration or collaboration with general agricultural extension.

1.2 Land husbandry and soil conservation

In the past, physical structures such as terraces and drains were considered the main soil conservation measures. The idea was to solve erosion problems by safely draining water away from the affected land. The soil erosion problem was often looked at from an engineer's point of view, and soil conservation was therefore not closely linked to farming practices or agricultural production in general.

The approach is now changing towards the concept of land husbandry, whereby good farming is seen as good conservation. Earlier thinking that conservation must form the base for production is being turned around to say that well managed production should form the basis for conservation.

Proper land husbandry aims at maintaining the land's productivity through good manage-

ment of soil, water, vegetation and animals. Well developed crops and other vegetation protect the soil from erosion. Soil conservation measures are therefore important components in sound land husbandry.

The main goal should be improved agricultural production on a sustainable basis through incorporating soil conservation as an integrated part of normal farming practices. A wide choice of soil conservation measures suitable to different physical conditions and cultural practices should be offered to farmers.

The key points for successful implementation of soil conservation could be summarized as follows:

- Soil conservation should be a natural component of all farming activities. This can only be achieved with active participation from the farming community to find suitable solutions in different agro-ecological and cultural environments.
- Extension and training on soil conservation should be integrated to include agriculture, livestock, and forestry since most farming systems in Tanzania are diversified.
- Low-cost simple techniques suitable for the local environment should be utilized to attain a high rate of implementation and sustainability.

2

SOIL EROSION AND LAND DEGRADATION

2.1 What is soil erosion?

Soil erosion is a process where soil is removed from one place and transported to another by water, wind and gravity. Geological erosion is a natural process continuously going on in the landscape. This relatively slow process can take thousands of years and is generally difficult to observe directly.

Destructive human activities such as deforestation, overgrazing and poor farming practices accelerate erosion processes which lead to severe land degradation. Erosion processes influenced by human activities are called *man-made* or *accelerated erosion*. This manual describes conservation techniques and approaches to tackle the problem of erosion and land degradation caused by human activities.

2.2 Soil erosion processes

Erosion is basically a levelling process where soil particles are carried downwards by the force of gravity. The main agents which loosen and transport the particles are water and wind. The following three types of erosion can be identified:

- Erosion by wind
- Erosion by water
- Erosion by gravity

The soil erosion process mainly involves three phases:

- Detachment
- Transportation
- Deposition

In the detachment phase, individual soil particles are separated from the soil mass, generally by water and wind. Separated soil particles are thereafter transported by water and wind and deposited elsewhere.

Factors influencing soil erosion

The extent of soil erosion caused by water and wind depends on several factors.

Rainfall erosivity

Rainfall erosivity refers to the intensity and amount of rainfall. High intensity of rain causes detachment of the soil particles. Large amounts of rain are likely to saturate the soil and then produce high rates of run-off.

Soil erodibility

Soil susceptibility to erosion depends mainly on the soil type, its ability to resist detachment and transport, and its water infiltration capacity. A most important factor is the soil structure which to a large extent depends on land management. Soils with a high content of organic matter have generally high infiltration capacity and high nutrition value which enhance crop growth and reduce the impact of erosion.

Sandy soils normally have low erodibility due to high infiltration rate and large particles.

Loams and soils with high content of silt and fine sand tend to have higher erodibility due to relatively low cohesion and infiltration capacity and high susceptibility to crusting.

Clay soils tend to have low erodibility due to high cohesion. Depending on the soil structure, infiltration capacity varies from extremely high to low. Poor soil structure with low infiltration ca-

pacity results in surface run-off or rill and gully erosion.

Slope steepness and length

Erosion increases with the steepness of the slope, as gravity forces contribute to the downward movement from splash erosion and the increased water flow velocities. The rate of erosion is also related to the length of the slope. On long slopes large amounts of water accumulate and cause heavy run-off, which carries away the soil particles. Both steepness and length of the slope can be changed through physical soil conservation measures such as terracing.

Soil cover

Soil cover can be in the form of vegetation (trees, crops and grasses) or dead plant material (mulch) or manure. Removal of the soil cover leaves the soil exposed to direct impact from raindrops and wind which can lead to erosion by wind and water. Various cultural and biological soil conservation measures improve the soil cover, reducing the impact of erosion.

Soil erosion by water

Water is generally the most significant agent of soil erosion. Preventive conservation measures should therefore minimize the impact of splash, sheet and rill erosion. These measures are described mainly in Chapter 3.

Rill erosion

Surface run-off can develop small channels (*rills*) in the field. This type of erosion is called *rill erosion*

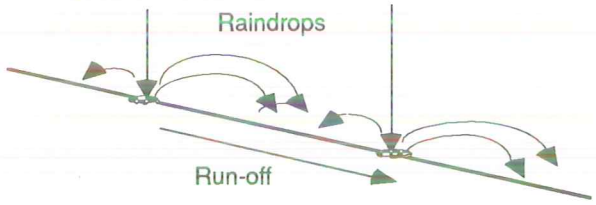
Photo 1. Example of rill erosion in a maize field on the steep slopes of Mt. Meru, Arumeru District. (Photo: Per Assmo)

and can easily be observed in the field (Photo 1). The extent of rill erosion depends on the amount and intensity of rainfall, type of soil, length and steepness of the slope and vegetation cover. Rills can be smoothed and removed by ordinary tillage practices.

Splash erosion

Splash erosion is also known as *raindrop erosion*. Particularly big raindrops with high velocity that hit bare ground cause detachment of soil particles. It is important to reduce the impact of splash erosion by good soil management and vegetation cover.

On sloping land, the detached soil particles have a gradual downward movement as shown in the picture below.



Gully erosion

Continuous removal of loose soil particles through concentrated run-off can develop into valleys called *gullies* (Photo 2). Gullies often develop from an advanced stage of rill erosion and cannot be smoothed by ordinary farming practices.

Gullies are commonly found on overgrazed pasture land, on farm land with poor farm management and along roads constructed without adequate drainage facilities.

Sheet erosion

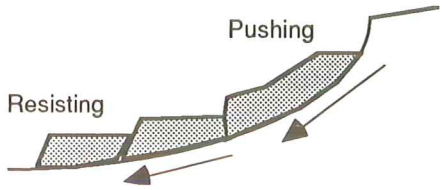
Soil can accumulate water to a certain maximum capacity. When the rate of rainfall exceeds the rate of infiltration, the topsoil, detached by splash erosion, is carried away by the *surface run-off*, also called *sheet erosion*. This process is generally slow and hardly visible. The impact of sheet erosion increases with the steepness and length of the slope. A rough surface can decrease erosion because of improved infiltration capacity and soil structure. The removal of topsoil, due to sheet erosion, reduces soil fertility severely.

Landslide

In cohesive soils of clay or loam, slopes can become unstable due to increased ground water pressure. As a result, the forces holding the soil horizons together are weakened.

Photo 2. Severe gully erosion in the plains of Arumeru District. (Photo: Charlotte Thege)

Such changes can lead to a rotational movement of a mass of soil where the upper part of an unstable slope pushes the resisting lower part. Consequently, a portion of land (and the land beneath it) slides down the slope. The process takes place rather suddenly and can threaten the lives of human beings and animals.



Landslide hazard depends on the nature of soils, rainfall intensity and the land use system. Preventive measures include reafforestation or belts of trees planted to absorb the water and to bind the soil.

Solifluction (Creeping erosion)

Solifluction (or creeping erosion) occurs generally on slopes dominated by loamy and silty soils. It is mainly attributed to the removal of trees and vegetation that once stabilized the sloping land. The soil saturated with water "flows" or creeps down the slope. Solifluction is a slow process compared to land slides. Preventive measures against solifluction generally include tree planting and drainage of the slope.

Stream erosion

Stream erosion is a process where soil is eroded particularly from the outer banks of rivers and streams. This type of erosion is often accelerated by farming activities too close to the river bed. Disturbance in catchment areas such as deforestation can cause floods of rivers and streams which accelerate river bank erosion. Preventive measures include conservation of the catchment areas and leaving the natural vegetation undisturbed along the river banks. Perennial crops, including trees planted close to the river bank can also further reduce erosion.

Soil erosion by wind

Wind erosion is the process where wind carries away loose topsoil particles from one place to another. Wind erosion occurs where the soil is bare and dry, especially in areas with light soils. For example in Arusha Region, the volcanic ash soils are susceptible to wind erosion.

On large open plains, the loss of soil by wind erosion can be reduced by planting windbreaks. Windbreaks are rows of trees planted across the direction of the wind. In small scale farming, agroforestry practices such as growing trees along field boundaries, around farm compounds, along soil conservation structures and scattered in the field are more suitable. Agroforestry species and their uses are further described in Chapter 6.

2.3 Causes and effects of soil erosion

Erodible soils and poor farming practices are some of the major factors influencing soil erosion and land degradation problems in Tanzania. Soil erosion results in loss of fertile topsoil and damage of soil structure on farm land as well as grazing land, leading to decreased agricultural production. Soil erosion also causes siltation of dams and hydroelectric plants, and destruction of infrastructure such as roads and railways.

Population pressure and poor farming practices

Poor farming practices is a general term for land use practices which extensively exploit and degrade land resources. The high potential areas of Tanzania are most important for agricultural production, including both domestic and export markets. High population pressure, and poor farming practices in many areas endanger the natural resources. Forest reserves are depleted and cultivation is practised on steep slopes without including any conservation measures (Photo 3). Long and narrow fields along the slopes coupled with farming operations up and down slopes accelerate soil erosion. Continuous growing of a single crop on the same piece of land for several years reduces soil fertility, gives lower yields, decreases vegetative cover and increases the risk of soil erosion.

Population pressure alone does not degrade land resources, but it creates a situation that requires good land management to enhance sustainable production.

Photo 3. Cultivation on very steep slopes in high potential areas of Arumeru District. Observe the deforestation on top of the hill. (Photo: Per Assmo)

Photo 4. Severely overgrazed land in low potential areas of Arumeru District during the dry season. (Photo: Charlotte Thege)

Overstocking and overgrazing

Most low potential areas of Tanzania are utilized mainly as grazing land. Depending on rainfall and soil type, each area has a certain capacity for natural vegetation growth or production of fodder for grazing animals.

This is generally described as the land's *carrying capacity*, expressed in the number of animals (livestock units) that can be grazed per area unit (hectare). If the number of grazing animals (current stocking rate) exceeds the carrying capacity, the area becomes overstocked.

Overstocking of animals generally leads to overgrazing when animals graze the pasture to an extent that the vegetation loses its capacity to regenerate (see Photo 4, previous page). The result is reduced production of vegetative material (fodder) and decreased production from the animals.

Overgrazing can totally deplete the vegetation cover. Excessive trampling of the soil surface by animals also reduces the infiltration capacity, exposing the area to soil erosion and total land degradation.

Deforestation

Trees, shrubs and other vegetation generally have a positive impact on the microclimate, soil structure and soil organic matter. The trees, roots and residues bind soil particles together and provide protection against water and wind erosion.

Deforestation is indiscriminate cutting of trees without replacement. Uncontrolled burning of forests can also result in removal of a large number of trees and vegetation. The problem of deforestation can be seen in high potential areas which lack arable land, fuelwood and cash income. The problem can also be seen in low potential areas where the limited numbers of trees are cut down for fuelwood or to clear the area for cultivation or tse-tse fly control.

Uncontrolled burning

Traditionally, many farmers in Tanzania set fire to vegetation and crop residues during land preparation. Uncontrolled burning practices deprive the land of its protection against soil erosion.

SOIL AND WATER CONSERVATION ON CULTIVATED LAND

3.1 Introduction

Farmers can intensify their production by including conservation in their farming practices. Instead of looking at conservation as purely a long-term investment, it is also possible to get quick returns in the form of higher yields. Soil conservation on cultivated land is a good entry point to conservation in general, as farmers can quickly see the benefits.

The land husbandry approach emphasizes protection of land from the impact of rain drops falling directly on bare soil. Farming practices which conserve water in the soil, as soil moisture for improved plant production, are encouraged and therefore soil and water conservation are discussed together.

As most small-scale farmers produce crops, livestock and trees on their farms, advice on soil conservation has to include all these aspects. A good balance between crop and livestock production is a key to sustainable farming. Fodder crops are grown on soil conservation structures and on parts of the farm that are not suitable for crops. Manure from productive stall-fed animals is brought to the fields to maintain the soil fertility.

Cultural/biological and physical measures

Soil conservation practices can be grouped into *cultural/biological* and *physical measures*. Even though the different measures are explained separately in this chapter, combinations of the techniques are needed to effectively control erosion and increase production.

Cultural and biological soil conservation measures

Cultural and biological measures are practices related to crop and soil management. Generally, cultural measures are farm management practices related to crop production, such as early planting, tillage practices and manuring. Biological measures involve the use of vegetation for soil protection.

Biological and cultural measures involve a relatively small amount of surface soil manipulation. These measures are sufficient for soil conservation on relatively gentle slopes and in highly productive areas where vegetation can easily be established.

Physical soil conservation measures

As the slope gradient increases, additional physical measures, such as terraces and drains, must be included to control erosion. Physical measures should always be combined with biological and cultural measures for optimal agricultural production.

3.2 Biological measures

Described below are some of the most common biological practices utilized for soil conservation and improved crop production. All these measures aim at improved vegetation cover and improved soil structure for erosion control.

Crop rotation

Crop rotation is the practice of growing different crops in succession on the same field.

This system can promote:

- Better use of soil nutrients, for example rotation of leguminous crops (beans) with cereals (maize).

  Crops with good vegetation cover could be included in the rotation to protect the soil and minimize the average soil loss over a number of years.

- Rotation of crops with different susceptibility to pests and diseases reduces this problem.

  The use of widely spaced row crops that are clean weeded also helps to control the build up of weeds.

- Forage legume based rotations are used to maintain soil fertility and soil structure. This is mainly attributed to dense vegetation cover and deep rooting of leguminous crops (see Section 3.3 on *green manuring*).

Mixed cropping

Growing two or more crops closely together in time and space, mixed cropping, results in more intensive use of the land than can be achieved with continuous cropping or crop rotation. Included under mixed cropping are intercropping practices where crops are arranged in rows. (compare Section 3.3 on *contour farming*).

Examples of mixed cropping include:

- Maize + Beans
- Sorghum + Pigeon peas
- Maize + Grams
- Coffee + Banana
- Maize + Pigeon peas + Beans
- Maize + Sunflower

Strip cropping

Strip cropping is an efficient soil conservation method with rotation of perennial crops (mainly pastures and fallows) with annual crops. The crops are grown in strips along the contours, ideally between grass strips, bunds or terraces. The effectiveness of the system depends mainly on proper plant population, root system and ground cover. Crops such as maize can be alternated with pasture. This practice is mostly effective on gentle to moderate slopes up to 20% and with relatively high infiltration capacity. The strips should generally have a maximum width of approximately 20m on gentle slopes decreasing to 5–7m on steeper slopes.

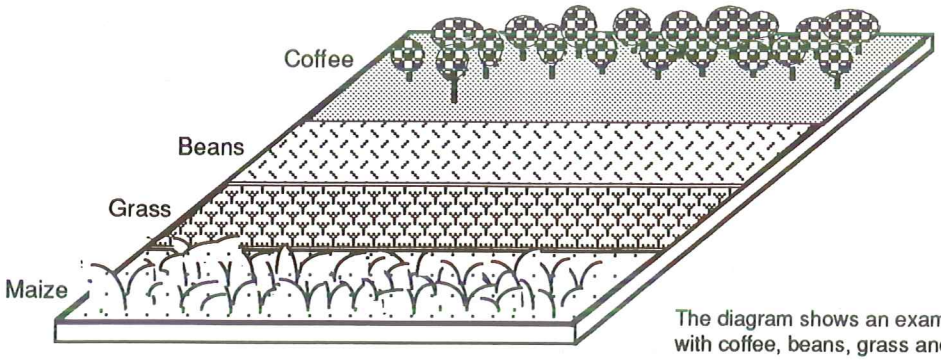
Grass strips

Grass strips can be established by leaving unploughed strips (width 0.5–2m) for natural grass to establish. For more productive grass strips, especially on small-scale farms, high yielding fodder grasses are introduced, for example, root splits or cuttings of elephant grass along the contour (Photo 5). These fodder grasses need protection against free grazing. Grass strips can also be interplanted with various types of trees suitable for intercropping.

Grass strips along contour lines are generally effective barriers to keep the soil in place, particularly on medium to coarse textured soils. Grass strips can be used to initiate formation of bench terraces (developed bench terraces).

Trash lines

The use of trash lines (Photo 6) is a practice where crop residues are collected from the farm and placed along contour lines. Trash lines provide a



The diagram shows an example of strip cropping with coffee, beans, grass and maize.

Photo 5. Strips of newly established elephant grass planted across the slopes. Mareu village, Arumeru District. (Photo: Per Assmo)

Photo 6. Trash lines laid across the slope to prevent erosion. (Photo: Arne Eriksson)

good environment for natural grass growth and reinforce this type of cross slope barrier which eventually develops into a bench terrace.

Wash stops

The main aim with wash stops is to use living plants or crop residues to filter water and hold back deposited soil particles. Decomposition of trash and its incorporation into the soil provide a good source of nutrients for both crops and grass on the bund.

Wash stops, like grass strips and trash lines (also called *permeable cross slope barriers*) are also used to develop bench terraces. (These methods of developing bench terraces are described in Section 3.4.)

Infiltration zones

Infiltration zones are belts of perennial vegetation with trash left on the ground. These can be used on slopes of 5–30%. They can substitute for terraces or be used in combination. Perennial vegetation may include crops such as bananas and tea.

3.3 Cultural measures

The cultural measures described below are farm management practices aimed at improved agricultural production and reduced soil erosion.

Contour farming

Contour farming is a practice in which all farm operations, including tillage, planting and weeding, are done along the contour. It is sufficient in itself for soil conservation on gentle slopes but should be used in combination with terracing on steeper slopes (Photo 7, p.14).

Early planting

Early establishment of a crop is recommended for improved vegetative cover to protect the soil, particularly during periods of heavy rains in the beginning of the rainy season. Having a crop on the land for most or all of the year reduces soil erosion. Such practices (relay cropping or sequential cropping), however, demand fertile soils and adequate rainfall.

Tillage practices

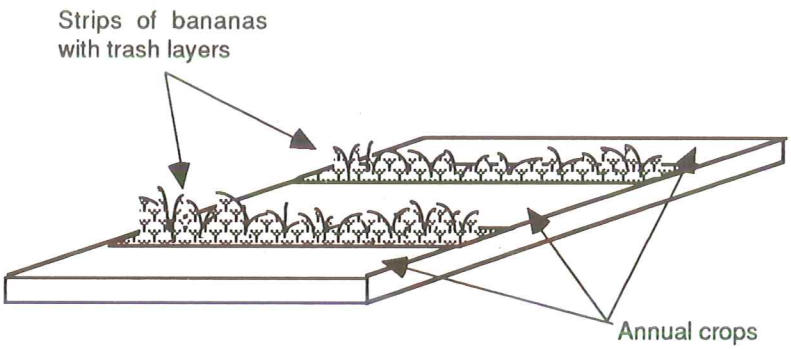
One method of soil and water conservation is to adopt suitable tillage practices for the soil, crop and climatic conditions. Generally, large clods increase the infiltration capacity. For this purpose, disc harrows and chisel ploughs are normally better than ploughs turning over the soil. Intensive tillage (ploughing and harrowing several times) can increase run-off and soil loss.

Zero tillage is a practice which includes no physical tillage operations. The practice utilizes herbicides to control weeds before planting or after harvest. Another practice is controlled burning of vegetation. Land preparation with minimal disturbance of the soil surface (small holes for each seed or narrow strips for planting) is known as *minimum tillage*.

Some general guidelines for tillage practices:

- All tillage operations should be carried out along the contour.
- Use the minimum number of tillage operations possible.

Infiltration zones



- Avoid harrowing if possible. Breakdown of clods decreases infiltration capacity.
- Incorporate crop residues and/or cow manure into the soil during tillage operations, or leave crop residues on the soil surface as soil cover.

Ridging

Ridging, also known as *listing*, is a land preparation practice making earth-bunds along the contours. The ridges can be constructed by hand, ox-plough, disc plough or ridger.

Different types of ridging are used in drier areas to increase infiltration of water and enhance increased crop growth. Row crops, like sweet potatoes, Irish potatoes and cassava, can be planted on either side or on top of the ridge (Photo 8, p.14).

Mulching

Mulching is spreading dead plant residues in the field to cover the soil. Mulch reduces run-off and minimizes water and wind erosion. It also reduces evaporation and hence improves the water balance. Decomposing plant materials provide organic matter to the soil; this results in improved soil structure and infiltration rate.

Examples of mulches are banana leaves, grasses, branches from fodder bushes and maize stalks. The effectiveness of mulch in controlling erosion varies with soil type. Course textured soils require more mulch or residues to control wind erosion.

Although mulching is an effective soil and water conservation measure there are limitations for the implementation such as competition in the use of crop residues for mulch or fodder for livestock. In areas with termites, mulching is not effective.

Organic fertilizers

Organic fertilizers include decomposed plant material or plants mixed with animal droppings. Incorporated into the soil, such a fertilizer improves soil fertility, structure and water holding capacity.

Farmyard manure

Farmyard manure is a good natural fertilizer. Both urine and dung contain nutrients which should be returned to the field. Farmyard manure should be spread out and buried in the soil. (See Chapter 5.)

Compost manure

Compost manure is a mixture of farmyard manure and organic matter (plant material) such as crop residues, sawdust, weeds, grass and kitchen waste. Ashes can also be added.

The simplest method to make compost manure is to place it in a heap and cover it for later use. The most effective, but labour-intensive, method is to dig a hole (common dimensions: 1 x 2m and 1m deep):

- First place a dry layer of crop residues in the bottom. Thereafter, deposit animal manure and organic matter layer by layer.
- Cover the pit with a thin soil layer and add water (50 litres) every third day. Turn the material over after two weeks, putting the upper layer down and vice versa.
- After four weeks, mix the contents once again, and cover. Imbed a stick to stand upright in the hole. When the stick comes out cold, the compost manure is ready to be used in the field.

Green manuring

Green manuring is the ploughing in of living plants just before flowering, This practice improves the fertility status of the soil and helps to control erosion. Leguminous plants are generally advisable for green manuring. *Crotalaria* spp *(Marejea)* is one example of a promising crop for green manuring in Tanzania. One reason for low adoption of green manuring is that during decomposition, some of the nutrients are not readily available to the plants.

3.4 Physical soil conservation measures

Introduction

The emphasis should really be on the cultural and biological measures, and only where these measures alone are not sufficient should they be combined with physical structures such as terraces, cut-off drains and artificial waterways.

A common criticism against physical soil conservation structures is that they reduce the land available for farming. It is therefore important

Photo 7. Developed bench terraces planted with elephant grass and agroforestry trees. Crops planted along the contour of the terrace. Ng'iresi village, Arumeru District. (Photo: Per Assmo)

Photo 8. A farmer planting on ridges across the slope. Mbeya Region. (Photo: Per Assmo)

that physical structures are utilized intensively for production of fodder, grass, trees or perennial crops. The farmer should preferably use the most cost-effective soil conservation methods. Always aim at conservation through increased agricultural production and combine physical measures with cultural and biological measures.

Terraces

In everyday language a terrace is a level piece of ground on a slope, but from American soil conservation standards a wider concept of terraces has been introduced. Thus, terraces are earth embankments, channels or combinations constructed across the slope (cross slope barriers) at suitable spacing and with acceptable grades to:

- reduce soil erosion
- provide for maximum retention of moisture for crop use
- reduce surface run-off water at a non-erosive velocity
- reform land surface
- improve farmability
- reduce sediment content in run-off water
- reduce peak run-off rates to installations down stream.

The construction of terraces can be done mechanically or by hand. A general recommendation would be that terraces should be constructed mechanically where mechanized farming is practised (gentle slopes) and by hand, or in combination with ox-plough on small-scale farms and on steeper slopes

Whether using impermeable cross slope barriers (excavated terraces) or permeable ones (grass strips, trash lines, bush hedges, stone lines), the end result in most cases will be the same: a gradual formation of bench terraces.

The time needed for bench formation is closely related to soil erodibility, maintenance and reinforcement of the structures. As a general rule there is less need for physical structures in high potential areas where vegetation can be easily established. It is, however, difficult to manage very steep slopes without introducing physical structures. In drier areas, it is often necessary to include physical structures for the purpose of trapping water to assist in establishing vegetative measures.

In order to minimize costs for soil conservation, different cross slope barriers can be alternated along the slope on the same field. A physical structure can be followed by one or several vegetative strips followed by a firm physical structure and so on.

The suitability of different terraces depends on many factors. Therefore, Table 1, which considers mainly the steepness of slopes, should be seen as a very general guideline

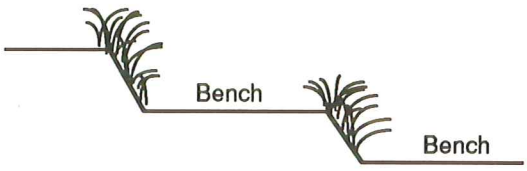
Land steeper than 55% should not be cultivated or used for grazing. Such areas should be planted with perennial vegetation or forest.

Table 1. Types of terraces and steepness of slopes

Type of terrace/ Cross slope barrier	Ground slope (high potential area)	Ground slope (low potential area)
Fanya juu terrace	steep slopes (30–55%)	up to 55%
Fanya chini terrace	up to 35%	up to 35%
Stone bund	on all slopes	on all slopes
Grass strip	on all slopes, combine with structures on steep slopes if needed	on all slopes in combination with water retention structures
Trash line	as for grass strips	all slopes except where termite problem exists
Retention ditches/Absorption channels	up to 20%, if steeper introduce infiltration pits	up to 20%, if steeper introduce infiltration pits
Ridge terraces: Narrow based Broad based	up to 15% up to 10%	up to 15% up to 10%

Bench terraces

Bench terraces convert a slope into a series of steps, with horizontal or nearly horizontal ledges and vertical or nearly vertical walls between the ledges.



Bench terraces can be constructed on the contour (level terraces) to minimize run-off, or with a slight gradient (graded terraces) to discharge excess water from farm land. (For discharge of water from farm land, see Section 3.6 and 3.7.) Bench terraces can generally be established in two ways, developed and excavated (constructed).

Excavated backward sloping bench terraces

Excavated terraces are dug into the slope. They are mainly used on steep slopes of 35-55%. They are labour-intensive and not suitable for shallow soils and result in loss of production in the first and second year after construction.

If a bench terrace is excavated into the slope by digging, the subsoil will be brought to the surface on the inner part of the terrace which becomes infertile. This manual therefore does not recommend this type of excavated bench terrace.

Modified bench terraces/orchard terraces

Modified bench terraces can be implemented on steep slopes of 35–55%. These are constructed by excavating a small ledge. The riser between each terrace will still be sloping (see Photo 9) and should be planted with perennial grass. These narrow terraces are best suited for perennial crops such as bananas and coffee.

Developed bench terraces

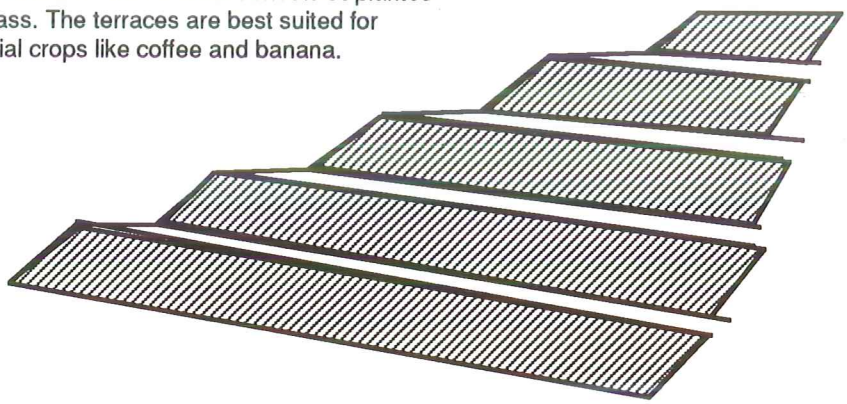
Developed bench terraces are the most commonly used bench terraces in Tanzania. These terraces are less labour-intensive than excavated terraces and generally more suitable for small-scale farms. They should preferably be implemented on relatively deep soils, since soil depth on the upper part of the bench otherwise would be too shallow.

These terraces are formed by constructing an embankment of soil (or alternatively a permeable cross slope barrier). When the soil between the embankments moves downwards (by erosion and tillage operations) it is trapped by the structure, gradually forming a bench terrace.

The most common methods used to develop bench terraces are *Fanya juu* or *Fanya chini* terrace and grass strips. Bench terraces can also be developed from trash lines and stone ridges. *Fanya juu* will develop faster than *Fanya chini*, trash lines or grass strips. Cross slope barriers should be repaired and maintained by filling low spots and maintaining ridges using soil from the lower side of the embankment.

Modified bench terraces on a steep slope of 55%

The risers between the terraces should be planted with grass. The terraces are best suited for perennial crops like coffee and banana.



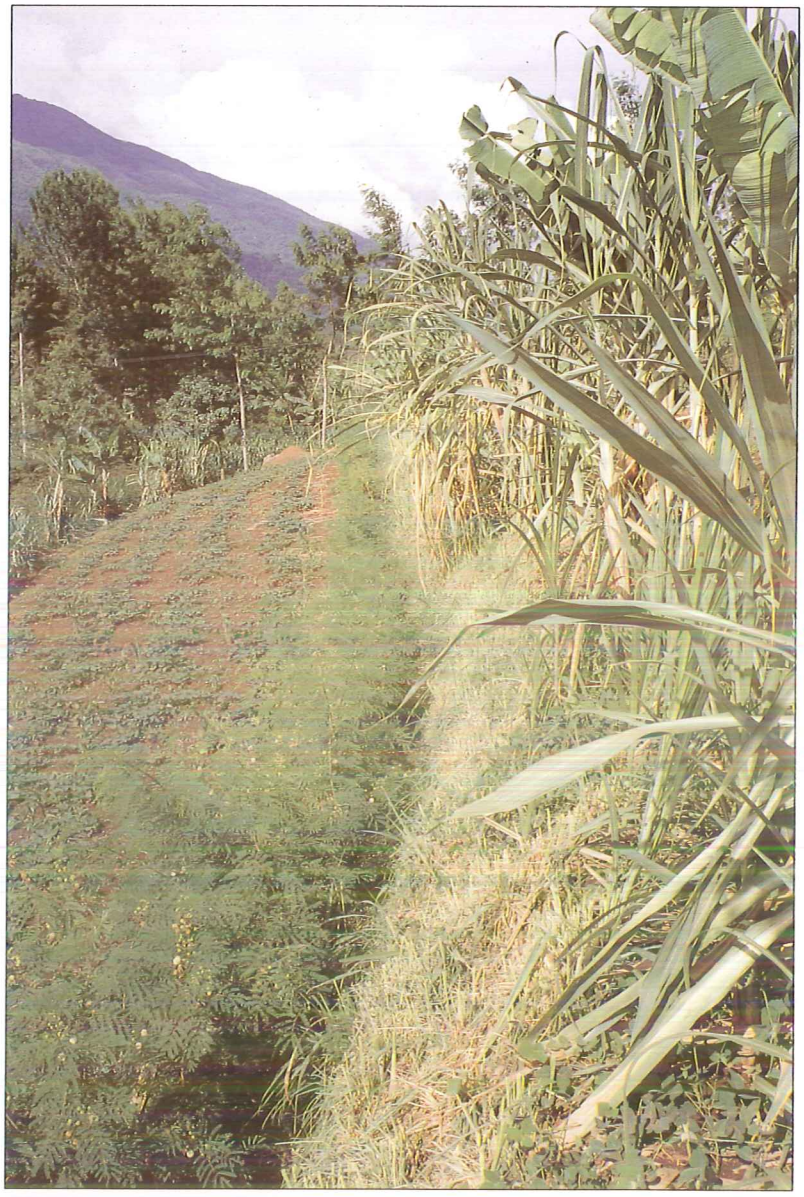


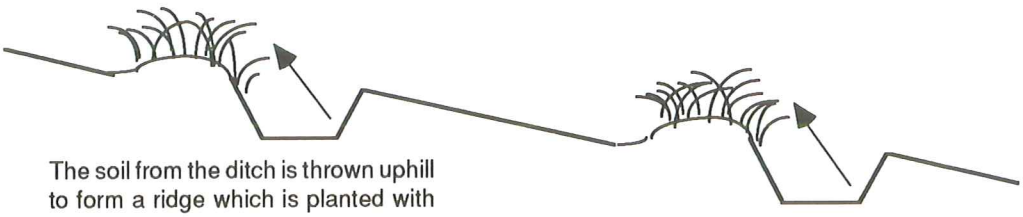
Photo 9. Forward sloping bench terraces. Observe the dense grass vegetation protecting the terrace riser. Fodder trees are planted on the lower side of the embankment. Ng'iresi village, Arumeru. (Photo: Per Assmo)

Fanya juu *terraces*

Fanya juu means that a ditch is dug and the soil is thrown uphill from the ditch to form a ridge. The ridge catches the soil that is moved downhill by erosion and cultivation. The ditches in *Fanya juu* terraces should be as narrow as possible to minimize loss of land for cultivation.

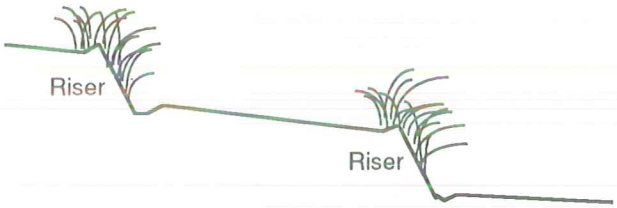
Fanya juu terraces can be slightly graded to discharge excess water from farm land, or level (on the true contour) to infiltrate water. As this type of terrace originates from dry areas, it is designed both for soil and water conservation. Often the ends of the terrace are slightly drawn uphill to store water behind the structure.

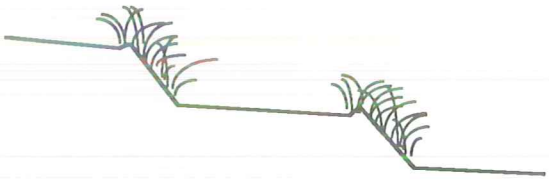
Experiences from Arusha Region have shown that a trench 0.5m wide and 0.5m deep can be used for both *Fanya juu* and *Fanya chini* terraces. In other areas these dimensions might need to be changed to suit the physical conditions. In dry areas it is common to plant bananas or fruit trees in the ditch. *Fanya juu* terraces should generally not be constructed on shallow soils.



The soil from the ditch is thrown uphill to form a ridge which is planted with grass

The ditches and risers are maintained by throwing the soil uphill. The *fanya juu* will gradually develop into a bench terrace. The riser of the terrace should have a slight angle and be covered with grass. When the bench terrace is fully developed, the ditch is normally reduced to a small furrow and can be planted with crops (see Photo 10, p.20).





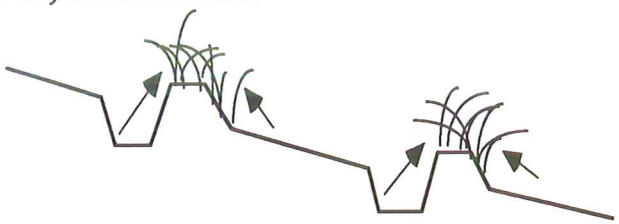
Channel terraces/Fanya chini terraces

When constructing a channel terrace (*Fanya chini* terrace) the soil is moved downhill from the excavated channel/ditch to establish an embankment. Channel terraces can be graded to discharge water, or they can be level. Level channel terraces require deep soils with high infiltration capacity. It should be noted that the *Fanya chini* model is not suitable on very steep slopes.

The following method is used to develop *Fanya chini* terraces:

1. A ditch, 0.5m deep and 0.5m wide, is constructed along the contour. The soil is placed below the ditch to create an embankment.

Fanya chini terraces



2. The embankment is planted with fodder grass and different types of trees. In high potential areas, trees can be planted on the lower side. In low potential areas, trees are planted on the upper side of the embankment.
3. Sediment, resulting from erosion, is scooped out of the ditch and put on the ridge together with soil from below the embankment to strengthen the structure. This exercise continues for two rainy seasons. The trench can thereafter be allowed to silt up, and gradually a bench terrace will develop.

On steeper slopes, repairs and maintenance must be done by moving the soil upwards (like a *Fanya juu*) to assist the development of a bench. Soil can be put on top of planted grass which continues to grow, stabilizing the embankment (see Photo 11, p.20).

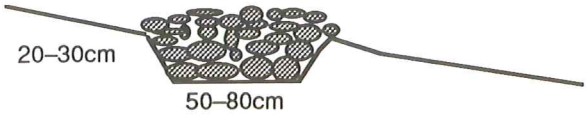
Both the *Fanya juu* and *Fanya chini* terraces will, with appropriate maintenance, develop into bench terraces. Choice of terrace depends mainly on climate, soil type and acceptance by the farmers (see Section 3.5).

Stone bunds/terraces

In stony areas, stone bunds can be constructed across the slope. This type of permeable cross slope barrier is effective in controlling erosion. Removing stones from the farm land will also provide more arable land and enhance mechanization. Conservation structures made by stones are very stable and can also be utilized in areas with high rainfall.

To establish a stable stone terrace, first construct a shallow ditch along the contour, where the stones are placed. If this is not done, the stone wall will slide down the slope due to undermining. The ditch should have a level bottom with a

width of 50–80cm and a depth of 20–30cm (see also Section 3.9 on *contour bunds*).



Ridge terraces

Ridges can be constructed by excavating soil from both sides to construct a contour bund. Ridges are usually constructed on gentle slopes of 5–10%. On mechanized farms oxen or tractor ploughing can be used to construct the ridges, but they can also be constructed by hand. Ridge terraces are generally level, used in low rainfall areas to retain and infiltrate water for crop or fodder production.

There are different types of ridge terraces. *Narrow based ridge terraces* are often used on small-scale farms in drier areas. Narrow based ridges normally have a width of 1m with ditches 0.5m. Both the ridges and ditches are used for crop production.

Broad based terraces generally have ridges with a width of 10–15m. Broad based terraces are most common in mechanized medium- to large-scale farms. The ridges are made wide and low so that tractors can pass over both ditches and ridges.

Wash stops (Permeable cross slope barriers)

Wash stops (permeable cross slope barriers such as grass strips and trash lines) reduce water flow velocity, and most of the water infiltrates into the undisturbed soil covered by such barriers. As sediment is deposited in wash stops, they gradually develop into bench terrcaces.

Example of grass strips planted to protect the soil against erosion.

Erosion and cultivation between the grass strips move soil downhill to build up a bench. For maintenance, and faster establishment of a bench, soil is excavated from below the embankment and put on the grass strip for reinforcement.

Spacing of terraces

Spacing between terraces can be expressed either in height between two succeeding terraces (vertical interval, V.I.) or width of a terrace (horizontal interval, H.I.) Since the gradient usually changes along the slope, a horizontal measurement is not suitable. The V.I. is therefore used to determine the spacing between terraces. The V.I. can be calculated, but more common is the use of a constant V.I. Which constant V.I. to use depends mainly on the following factors:

- Rainfall intensity and amount
- Slope steepness and length
- Soil erodibility
- Expected future use of the land

Generally, a smaller V.I. is used on gentle slopes, especially in drier areas where water conservation is important. A smaller V.I. will reduce the spacing between terraces. A bigger V.I. can be recommended on steeper slopes with deep soils to avoid very narrow spacing between terraces. The most commonly used constant V.I.s are as follows:

Slope 5–25% = V.I. 1.2–2.0 metres
Slope 25–55% = V.I. 1.8–2.2 metres

Chapter 8 describes how to measure and calculate spacing of terraces.

Terrace gradients

Terraces can be constructed along the true contour (level terraces) or at an inclination (graded terraces).

Photo 10. Construction of *Fanya juu* terraces. Ekenywa village, Arumeru District. (Photo: Arne Eriksson)

Photo 11. Channel terraces (*Fanya chini* terraces) constructed and planted with fodder grass in low potential areas to reduce erosion and increase water infiltration and soil moisture. Oloitushula village, Arumeru District. (Photo: Paul Rimmerfors)

Level terraces

Level terraces are constructed on soils with medium to high infiltration capacity, to conserve and infiltrate water. Although these types of terraces are mostly used in low rainfall areas, they can also be used in medium to high potential areas with high infiltration capacity and stable soils.

To avoid large concentrations of water that might occur in depressions, level terraces should not be too long. This problem can be reduced by making the channel terraces discontinuous, blocking channels at every 100–150m. In the layout work, the ends of the terraces can be slightly turned uphill to avoid water flowing out. (Further information on different techniques to retain and infiltrate water is given in Sections 3.9 and 3.10.)

Graded terraces

In soils with relatively low infiltration capacity, and on steep slopes, it is necessary to allow for water discharge from farm land to avoid breakage of structures and/or waterlogging. This can be done by constructing graded terraces.

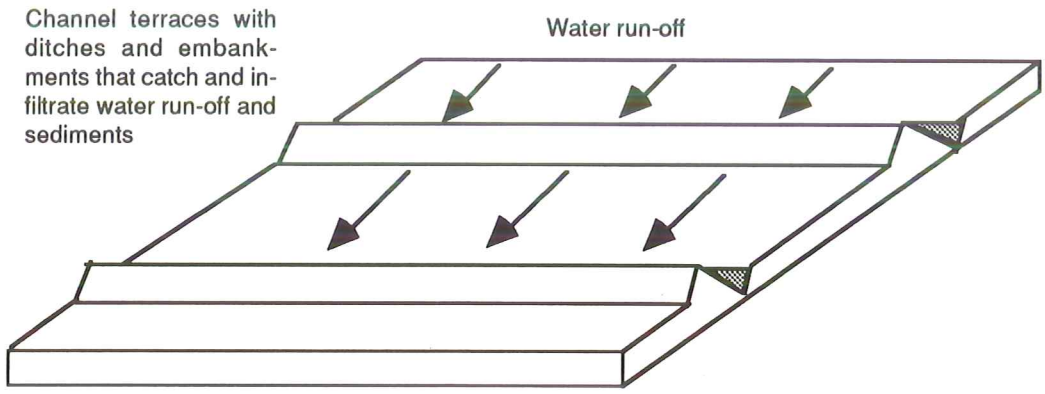
It is very important that efficient waterways exist for discharge of the water to avoid problems of gully erosion caused by the concentrated water run-off. Graded terraces should not be more than 150–200m long to avoid breakage of the structure and erosion in the channels. The following gradients towards a natural discharge area or artificial waterway are generally recommended:

- In erosion resistant soils (clay) 1%
- Common soils (loam) 0.5%
- In erodible soils (silt & sand) 0.25%

3.5 Important factors for construction of terraces

It is important to know the physical characteristics and cultural practices of a locality before deciding which type of terrace to be used. The following criteria could be used as a basic guideline for implementation of physical soil conservation measures:

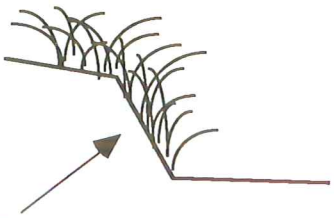
1. *Are physical measures really needed?* Sometimes a change in farm management (incorporation of cultural and/or biological soil conservation measures) can be enough to reduce soil erosion to an acceptable level.
2. If physical measures are needed, the following factors should be observed: Rainfall intensity and amount, slope steepness and length, soil erodibility, expected future use of the land and availability of labour for construction.
3. One must decide if the physical structures should aim at retaining or discharging water. Infiltration of water into the farm land avoids problems of discharging water and increases available soil moisture.
4. Since the farmer is the one constructing the terraces, it is important to select a type of terrace that is suitable for the land and physical conditions in the area and accepted by the farmer.
5. All physical conservation structures need *maintenance*. Below are some general rules for maintenance of terraces:
   - Repair breakages in the structures and fill up low spots on the terrace edge. This main-



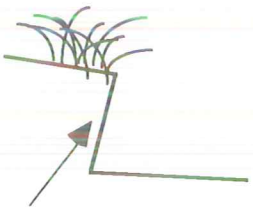
Example of channel/*Fanya chini* terraces constructed along the true contour, level terraces.

tenance is especially important during the first years.

- Plant new grass on bare spots to increase the density of vegetation on the terrace.
- The riser of the terrace should be slanting and planted with grass. (Only on very stable soils, the riser can be more or less vertical.) Do not excavate the riser.



Riser at correct angle



Riser at wrong angle

REMEMBER!

All types of terrace embankments should have good vegetation cover (grass) to be productive to the farmer and prevent erosion. Both the terrace edge and the riser should be planted. The final vegetation cover should be dense, without gaps, to stabilize the structure.

3.6 Cut-off drains

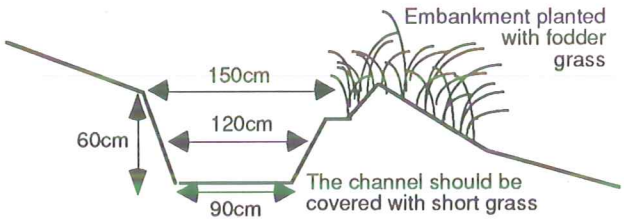
Cut-off drains (also known as *stormwater drains* or *diversion ditches*) collect and discharge water flows, protecting the land below the drain. They should always be combined with other soil conservation practices.

Cut-off drains should only be constructed if the need is quite evident and safe discharge points exist. Cut-off drains most often affect several farms; therefore, communal solutions must be emphasized for construction and maintenance of the structure.

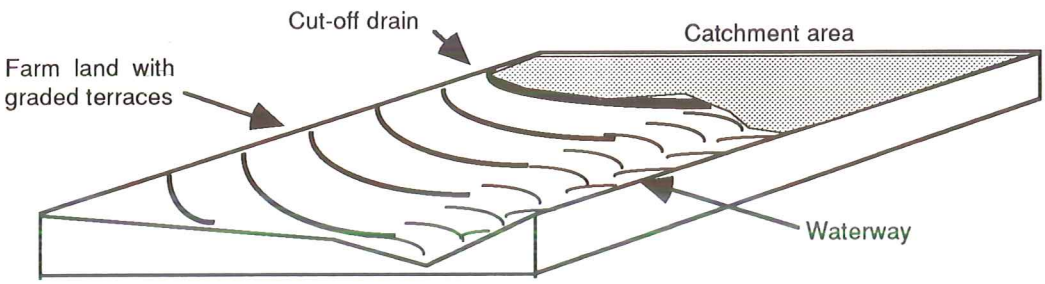
Cut-off drains together with graded terraces (drains and terraces are given the same gradients) convey water from the field and into suitable drainage areas. If drainage areas or natural waterways do not exist, cut-off drains must be combined with construction of an artificial waterway.

Dimensions of a cut-off drain vary depending on the discharge of water from the catchment area. The following dimensions can be used as a general guideline for small catchments (less than 10 hectares). Widths of 90cm, 120cm and 150cm for bottom, middle and top dimensions respectively and a depth of 60cm are usually used for a cut-off drain.

Pegging and digging of a cut-off drain should start from the outlet to locate the exact discharge point. The cut-off drain should be strengthened with short grass in the channel and preferably fodder grass on the embankment. Never plant annual crops on the embankment.



As with all physical structures, a cut-off drain needs regular *maintenance*. Sediment in the trench should be removed to maintain the gradient and strengthen the embankment. The figure below shows an example of a cut-off drain that diverts water into a waterway. Graded terraces drain excess water from the farm land.



3.7 Artificial waterways

Water from cut-off drains and graded terraces should be discharged into natural watercourses (rivers and streams), or into non-erodible areas such as stony ground, permanent pasture with good vegetation cover or forest areas.

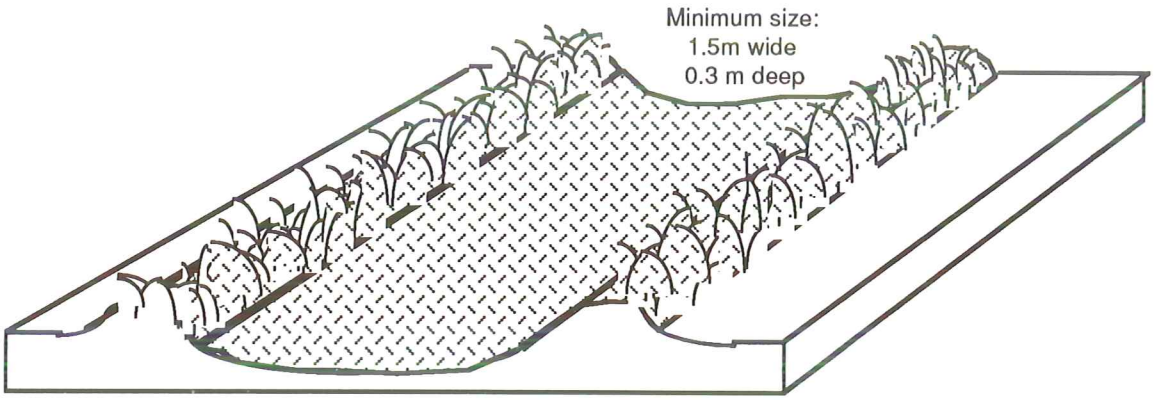
If this is not possible, an artificial waterway has to be constructed. An artificial waterway is an open shallow trench covered with short grass. Such grassed waterways are not stable on slopes steeper than 25% and therefore need further protection. Such techniques are generally the same as those used in gully control (see Chapter 4).

The size of a waterway depends on the amount of water coming from the catchment area. As a general guideline, the waterway should be at least 1.5–3m wide with a depth of 30–50cm. The depth of a waterway is related to the width in the following way:

Width	Depth
up to 3 metres	0.3 metre
3-6 metres	0.4 metre
more than 6 metres	0.5 metre

The waterway should have a thick short grass cover to prevent erosion. It should not be used as a footpath or cattle-track. The embankments of the excavated waterway can be planted with perennial fodder grass, although this grass should be harvested by hand and never by direct grazing.

Excavated cross-section of an artificial waterway



3.8 Water conservation and water harvesting in small-scale farming

As soil conservation uses the principles of retaining water in the soil, we cannot separate water conservation from soil conservation. Water conservation is a challenge to the extension worker since structures for water retention have to be carefully designed to avoid breakage which causes erosion and waterlogging damage.

Experience from use of specific water harvesting methods in Tanzania is limited; therefore, the principles and techniques described in this chapter should be seen as basic guidelines that offer some options to be tried. The techniques are closely linked to the soil conservation methods described earlier in this chapter.

Principles of water conservation

Water conservation aims at preventing surface flow of excess rain water and prolonging the time available for infiltration.

Where conservation of water—preventing runoff and keeping precipitation where it falls—is considered to be sufficient to increase the available soil moisture for crops; standard technique of developing level bench terraces from *Fanya juu* terraces or other wash stops is suitable.

Other common techniques to retain and increase infiltration of water into the soil include level channel terraces (*Fanya chini* terraces/infil-

tration ditches), ridging techniques and different types of wash stops. Different types of tillage practices also conserve moisture in the soil.

Principles of water harvesting

Water harvesting is the collection and concentration of water run-off for the production of crops, fodder, pasture or trees, for livestock or domestic water supply, or for other productive purposes.

All water harvesting systems include a *catchment area* and a *storage component*. Systems with *internal catchments* collect the water run-off within the cropped area. *External catchments* collect the water run-off from outside the cropped area.

Since there are tremendous variations in soil, crop water requirement and rainfall, calculations to establish the ratio between area yielding run-off to area receiving run-on cannot be accurate. For the introduction of water harvesting systems, simple field trials have to be carried out in each locality.

Soil requirements for water harvesting

Generally the soil characteristics required for efficient water harvesting should be the same as for irrigation.

- *Soil texture:* Medium textured soils, such as loams, are best.
- *Soil depth:* Soils which are less than one metre deep are poorly suited for water harvesting.
- *Soil infiltration rate:* The soils of cropped areas should be sufficiently permeable to supply adequate moisture to the crop root zone without causing waterlogging problems. On the other hand, a low infiltration rate leads to high run-off, which is desirable for the catchment area. The requirements of the cultivated area are most important.
- *Soil stability:* Avoid soils which crack on drying (especially vertisols or "black cotton soils"), and unstable sandy soils as these do not form stable bunds.
- *Ground slope:* Water harvesting is not recommended for areas with slopes greater than 5% due to uneven distribution of run-off and large quantities of earth work required.
- *Crop choice:* Select crop varieties suitable for semi-arid conditions, considering the following characteristics: short growing season, drought adaptation with a degree of tolerance against temporary waterlogging.

3.9 Water harvesting from internal catchments

The major advantages of water harvesting techniques from internal catchments is that they are simple and cheap. There are few problems with turbulent flow which causes soil erosion. Less water loss means that a smaller ratio of catchment per cultivated area is needed.

Many water harvesting systems with internal catchments are used for tree planting. At the lowest point, a simple hole or ditch is dug to increase the moisture available to the seedlings. If annual crops are cultivated, a basin with a level bottom can be constructed to avoid uneven water distribution, unless a contour ridge-type system is used.

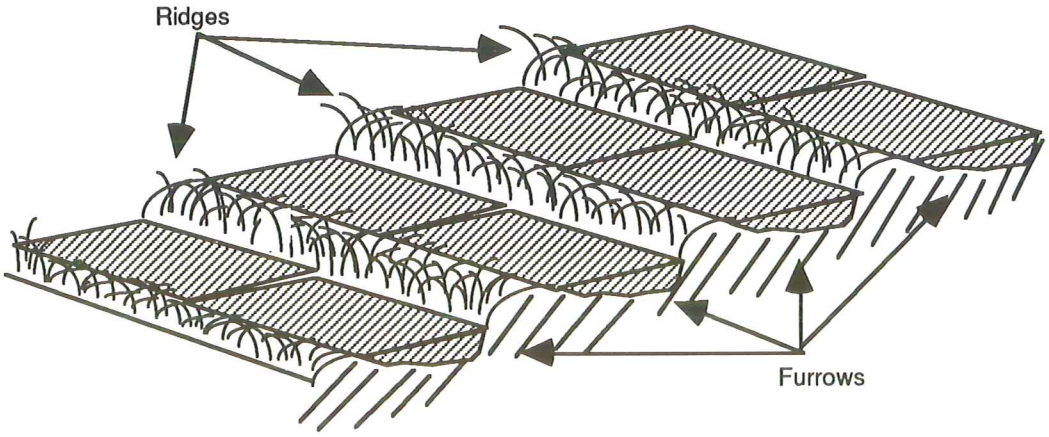
Ridging and tied ridging for crop production

Making ridges and furrows, and then damming the furrows with small mounds or ties generally increase surface water storage. The ridges can have a width of 0.5–2m. The structure should be smooth to be suitable for plant production.

The furrows between the ridges store the run-off water to enhance infiltration into the soil. Furrows should be on a gentle grade (0.5%) to assist run-off if the ties fail. Spacing between ties could vary from 5–10m. Ties should be lower in height than the ridges so that the ties fail along the furrows before the ridges fail down the slope.

The construction of tied ridges is mainly associated with mechanized farming because of the high labour requirement, but it is quite possible to use hand labour. There can be a danger of soil erosion if the ridges are overtopped and broken, since the water temporarily stored in the depressions is suddenly released.

There could also be a back-up system of conventional graded channel terraces to prevent damage if the ridges do overtop or fail. A simpli-



fied model of pitting (digging small basins to catch and store water) can be used as an alternative to tied ridging.

Matengo pits

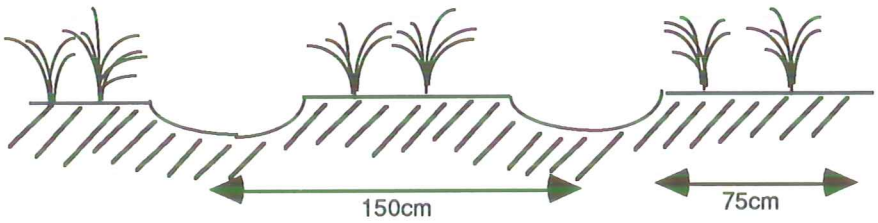
The Matengo pit is a traditional soil and water conservation method developed by the Matengo people for farming steep hillsides in an area receiving an annual rainfall of 1,000–1,250mm.

Grass is cut from the area to be pitted and laid out in stripes about 60cm wide on a square grid pattern with sides of about 180–300cm. Soil from the centre of each square is then removed with a *jembe* and spread on top of the cut grass. When completed, there is a circular hole about 90cm in diameter and 30cm deep surrounded on all sides by beds underlain by cut grass. Crops are planted on the raised beds. Weeds are thrown into the pit to form a compost.

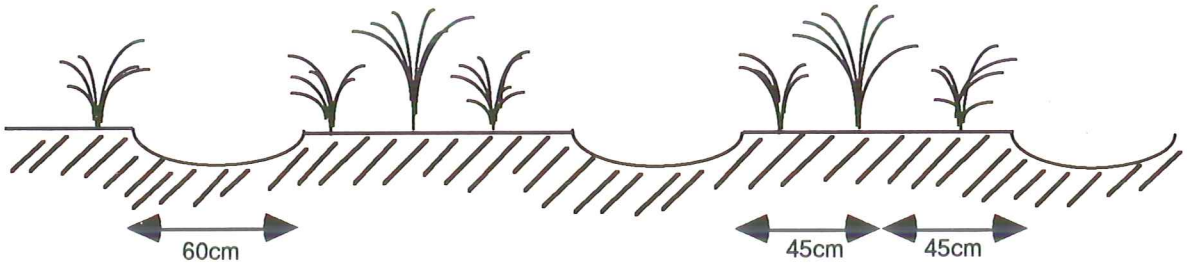
The pits are sufficiently large to accommodate run-off from even the most intense storms, so run-off from the land is completely eliminated. Legumes and non-legume crops are grown in rotation, and a new pit is dug on the site for the former beds every one or two years. Although this method was developed for areas with relatively high rainfall, there is definitely a great potential for the use of Matengo pits in drier areas.

(Broad) bed and furrow system

Surface drainage on gentle slopes can be done by transforming the soil into beds. This system is particularly suitable for vertisols in areas with dependable rainfall averaging 750mm or more but could also be used in other areas. The beds can vary in size depending on crop planted and soil characteristics. The ridges can be constructed by hand (for smaller areas), ox-plough or tractor.



Example of a bed and furrow system with a single crop.

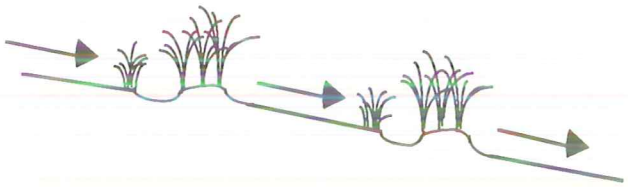


Example of a bed and furrow system implemented with intercropping.

Contour bunds (furrows) for crops

The contour bund furrow is a simplified technique of ridging. The principle is similar to conservation bench terraces (CBTs) but requires less soil movement than the CBTs described below.

Ridges for crop production are normally 20cm high with a width of around 50cm (with furrow uphill) and a minimum of 1.5m apart. The crops are planted on strips or in rows on the ridge, with the catchment area left fallow. Sometimes an additional strip of crop is planted also on the upper ledge on the furrow as shown in the picture below.



Conservation bench terraces

The conservation bench terrace (CBT) is a more advanced model of contour bund. A part of the land surface is left uncultivated to serve as a catchment; it provides additional run-off onto level terraces on which crops are grown. The level benches can be developed from *Fanya juu* or *Fanya chini* terraces.

The size of the catchment and run-on area (cropped area) depends on soil characteristics and crop choice. CBTs can generally be constructed on slopes ranging between 5–15% depending on soil characteristics. As the slope gradient increases, the catchment area should decrease. If there is a risk that run-off from the catchment area will be greater than can be absorbed and stored on the terrace, there must be outlets at the ends of the terrace which can discharge water into grass waterways or other safe disposals.

Tree micro-catchments

Negarim micro-catchments are U- or V-shaped basins surrounded by small earth bunds with an infiltration pit in the lowest corner of each. (The *negarim*, or bunds, were developed in Israel.) Run-off is collected from within the basin and stored in the infiltration pit. Micro-catchments are usually used for growing individual trees or bushes.

The size of micro-catchments (per unit) normally range between 10 square metres and 100 square metres, depending on the species of tree to be planted. Bunds should be at least 25cm in height to avoid the risk of overtopping and subsequent damage.

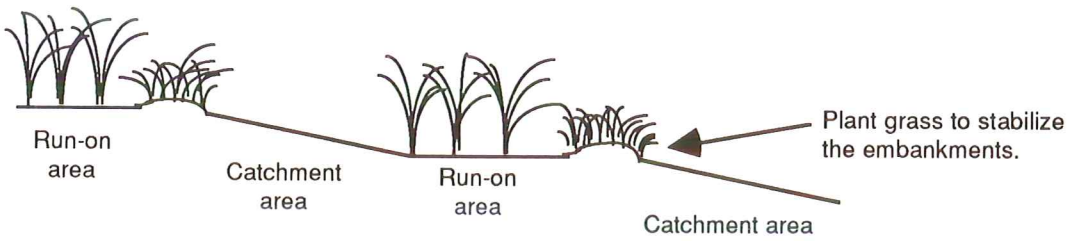
Contour bunds for trees

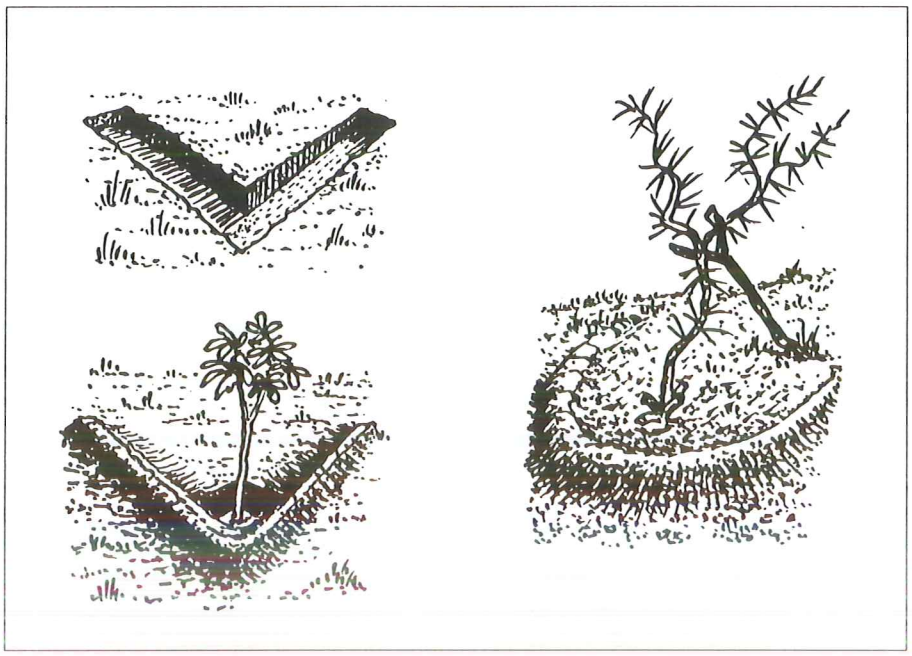
A contour bund for trees is a simplified form of micro-catchment using contour bund/furrows. The bunds follow the contour at close spacing, and small earth ties divide the bunds into individual micro-catchments.

Common sizes of micro-catchments are around 10–50 square metres. Bund heights vary, but are about 20–40cm, depending on the prevailing slope. Bunds should be spaced either 5m or 10m apart. Cross ties should be at least 2m long at a spacing of 2m to 10m.

Semi-circular bunds

Micro-catchments can also be constructed as semi-circular bunds. The half-circle earth embankments are constructed with the tips of the bunds along the contour. Semi-circular bunds of varying dimensions are used mainly for rangeland rehabilitation or fodder production. The technique is also useful for growing trees and shrubs and has in some cases been used for growing crops.





Tree micro-catchments can be U-shaped or V-shaped basins with an infiltration pit in the lowest corner.

If the amount of water harvested exceeds the infiltration capacity within the farm, it can cause severe problems of erosion or waterlogging. Water harvesting should therefore be done with caution.

3.10 Water harvesting from external catchments

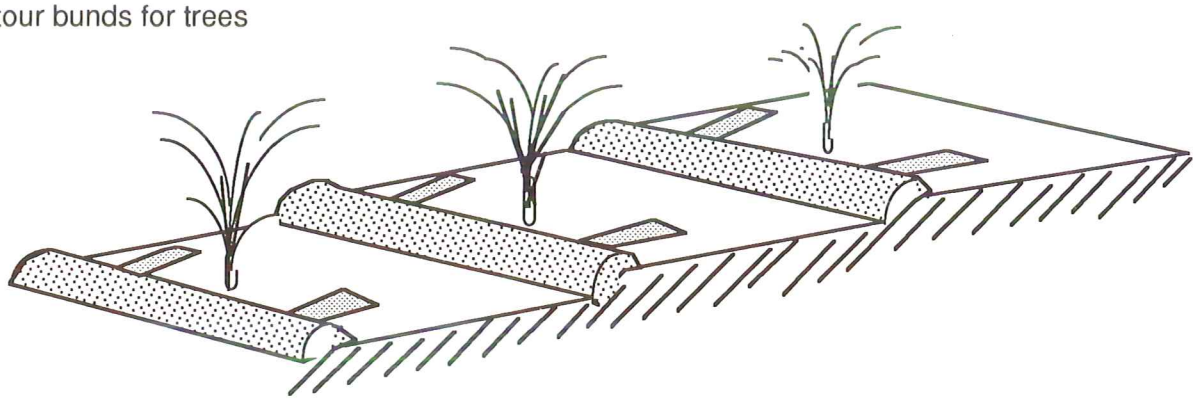
Water harvesting from external catchments can be done in different ways. A common practice is the collection of water from catchments outside the field (roads, home compounds, market places) and leading it into terraces and ditches for increased water infiltration on farm land. Such water harvesting can drastically increase crop yields in areas where rainfall is insufficient for reliable crop production.

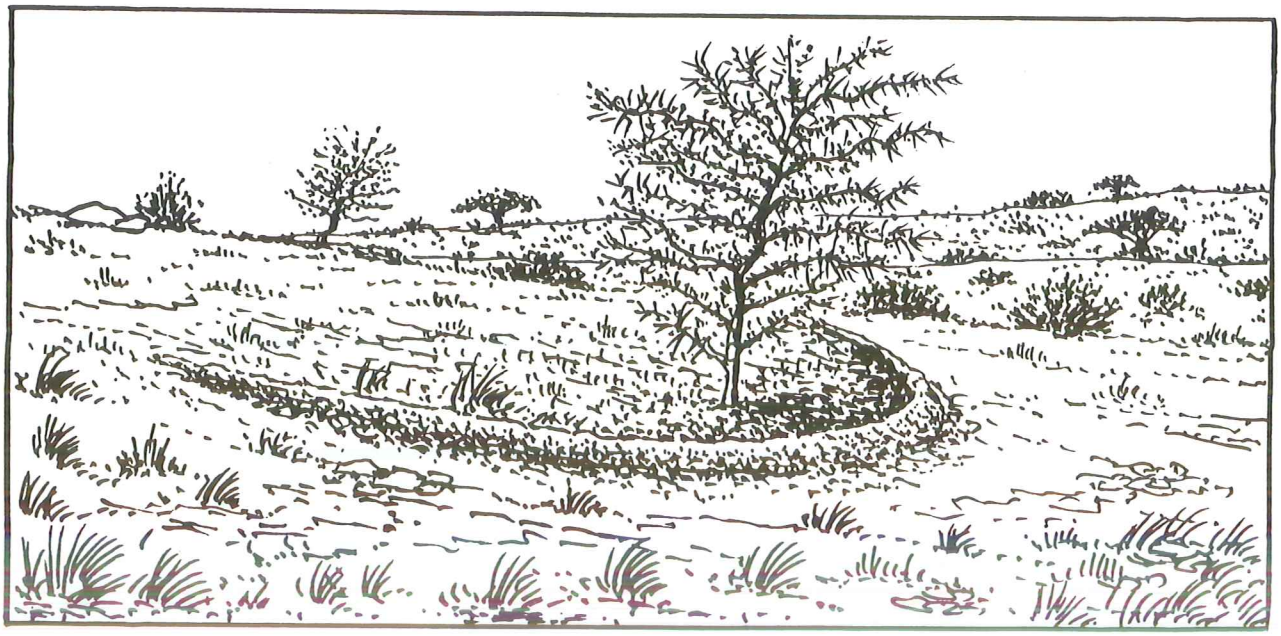
Run-off farming in level basins

A level basin system consists of hand dug earth bunds, which surround the plot and diverge as collection arms upslope of the plot in order to increase the catchment area. Water can also be collected from a road or any other suitable area.

Contour bunds divide the plot into basins (similar to basin irrigation). The contour bunds are equipped with spillways for controlled flow of water from the upper basin to the lower ones. The height of the spillway dictates the quantity of water stored and allows excess run-off to drain into the lower sections.

Contour bunds for trees





Semi-circular microcatchments allow *Acacia tortilis* to grow and mature more quickly in dry areas.

An average spillway should have a height of at least 10cm, and the free board required would need to be at least 15cm. The width of a spillway (or the sum of the spillways) in metres should be equal to half the catchment area in hectares. The width of the base of the bunds should be at least twice the height.

Contour stone bunds

The techniques for constructing stone bunds have been described in Section 3.4. *Contour stone bunds* used for water harvesting should be level (along the true contour).

Generally, stone bunds do not need any spillways since these are stable structures which filter run-off and capture sediment. The water and sediment harvested lead directly to improved crop performance. This technique is well-suited to small-scale application on farmers' fields, given an adequate supply of stones.

4

GULLY CONTROL

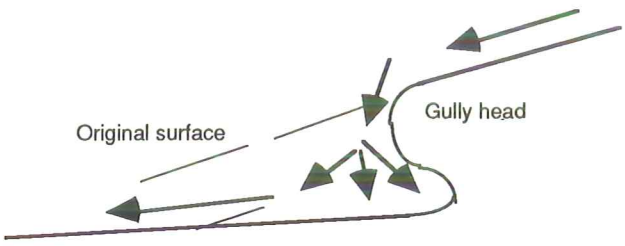
4.1 Introduction

While gullies are obvious and often spectacular, there is a tendency to over-emphasize the importance of gully control. In terms of damage to agricultural land or loss of agricultural production, gullies are overall less important than other forms of erosion.

Therefore, emphasis should aim at prevention of new gullies developing rather than reclaiming the gully area. The cheapest and simplest way is generally to implement preventive conservation measures in the catchment area above the gully to minimize run-off into the gully. The gully is thereafter closed off, planted with vegetation and left to heal.

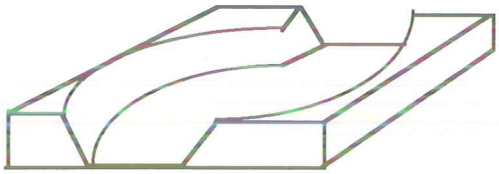
4.2 Erosion processes in gullies

At the head of a gully a "waterfall" type of erosion cuts back into the slope. The flow over the floor will deepen the gully. This deepening does not stop until the gully has reached solid rock.

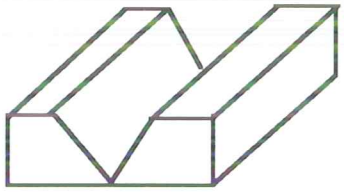


The deepening makes the sides of the gully unstable and causes movement of the soil from the sides to the bottom. In this way the gully is not only deepened but also widened.

Lateral erosion



Vertical erosion



Causes of gully erosion

Gullies occur more on overgrazed grassland in semi-arid areas than in high potential areas where better vegetation cover protects the soil. Gully formation is normally caused by increased surface flow, but a contributing factor can also be piping caused by subsurface flow creating underground channels which collapse and contribute to gully growth.

Main causes of increased flow to a gully include:

- Deterioration of vegetation in the catchment from clearance and cultivation, overgrazing, deforestation, fire, drought;
- Concentrations of flow caused by roads, footpaths, cattle tracks, storm drains, bunds, dam spillways;
- Heavy rains.

Damages caused by gullies

The land covered by the gully system is more or less totally lost for productive purposes. Gullies provide deep drainage that rapidly removes run-off and lowers water tables. Gullies are difficult to cross and so divide the land and make accessibility difficult. Gullies contribute a large proportion of the sediment load of streams and rivers. Some gullies may undermine and damage important structures such as roads, bridges, buildings and power lines.

4.3 Techniques for stabilization of gullies without piping

To counteract the cause of a gully, one can use several measures.

- Reduce the concentration and total amount of run-off from the catchment through proper conservation measures.
- Divert run-off away from the gully head by use of a cut-off drain.
- Restore the ability of the gully area to resist flow through improved vegetation cover.
- Protect the gully head, sides and floor with vegetation and/or various physical structures.

4.4 Techniques for stabilization of gullies with piping

These are the same principles as for gullies without piping. However, certain additional aspects should be considered.

- If piping is not controlled, structures put in the gully may be undermined or by-passed.
- Any measures increasing surface ponding and the rate of infiltration (for example, storm drains, terraces) may make piping worse.
- The objective is to have slow, steady and uniform infiltration over the entire area. A healthy grass cover is the most effective but may be difficult to establish in dry areas.

4.5 Gully control

There is a difference between active, V-shaped gullies and stabilizing U-shaped gullies. It is important to establish whether the gully is still growing, or if it has reached its maximum and is now naturally stabilizing. It is also necessary to know the soil depth in the gully to establish the potential damage that would be caused if the gully is left to develop further.

Taking these factors into consideration, a simple cost-benefit analysis should be done before deciding on gully control works. Often, big gullies are really too expensive to treat.

Depending on availability, wooden materials, stones or live materials can be used. Structures made of stones and live materials (sisal, euphorbia, grasses) are more durable and therefore more useful in places where grasses and other vegetation are not expected on their own to resist the erosion.

This text refers mainly to small- and medium-sized gullies. However, if a big gully is threatening expensive infrastructure (houses, bridges, roads), it must be treated, often at high costs.

Control of gully areas

As a general rule, it is always preferable to control gullies by vegetation rather than physical structures. The following aspects should be considered:

- Herding or fencing to keep grazing livestock out,
- Simple physical structures to slow down the flow and trap silt so that vegetation can regenerate, at least locally,
- Carefully selected suitable planting material to supplement or protect and "nurse" the natural vegetation.

Control of gully floor

Control of gully floor in U-shaped gullies on gentle slopes and gullies with small water flow can be done with wooden single row checkdams and different types of thresholds/scour-checks. Thresholds are strips of erosion-resistant material aligned across the flow, level with the gully floor at intervals (1–4m) along the gully. The depth should be approximately 15cm. The objective is to spread out the flow and limit erosion to the "threshold" level. This technique is also used for stabilization of waterways (Photo 12).

Live checkdams (of sisal, vetiver grass) may be

planted in strips across the flow in combination with thresholds to assist establishment. In shallow channels, preferably only low growing vegetation should be used, as sediments building up in the channel must be controlled to leave sufficient cross-section for the flow.

Control of gully head

The eroding waterfall can mainly be approached in three ways: dam construction downstream of fall, protecting and sloping the channel with stones and construction of fall structures.

Control of gully floor in active V-shaped gullies

In the control of gully floors in active V-shaped gullies, the choice of structures depends on available materials and costs. If live materials are readily available, these should be given priority. Good examples are trees and bushes that can be propagated with stem cuttings such as *Commiphora* spp, *Gliricidia*, *Euphorbia* and *Bamboo*.

Single- and double-row brush wood dams can often have live posts which do not rot, are not

Example of dam construction downstream of fall.

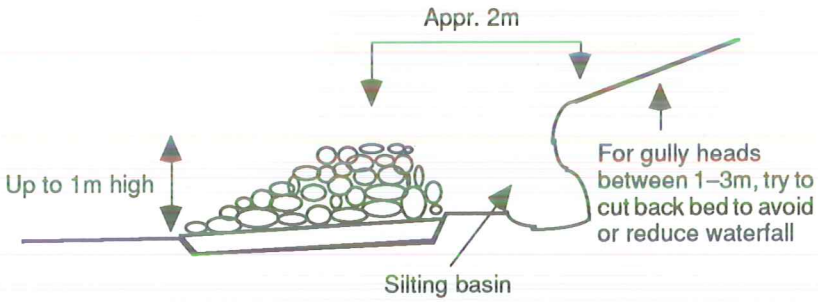
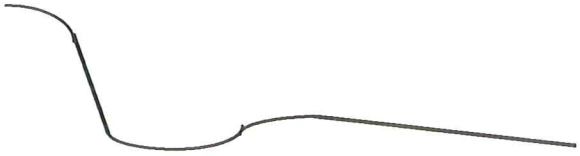


Photo 12. Stone thresholds constructed in a waterway. (Photo: Arne Eriksson)

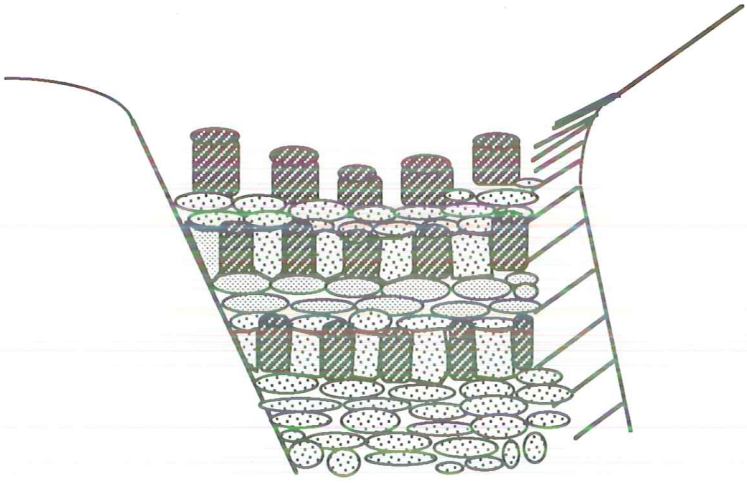
Example of protecting and sloping the channel using stones



Longitudinal section before measures

Excavate a trench of length 1.5 times the height of the gully head along the gully bed. Fill up the slope and trench with small stones in the bottom and larger stones on top.

Example of fall structures constructed with stones in a narrow gully with steep gradient



attacked by termites and will become stable in the ground after rooting. The height of these poles must be trimmed regularly to maintain sufficient cross-section for the flow.

Trees should not be planted in the water channel since that may restrict the flow and increase local scouring.

Side walls of a gully

Side walls are normally left to stabilize naturally. However, if the walls are not very steep (less than 1:1), trees and/or grass can be planted on them.

Usually the erosion of a bend can be stopped by planting elephant grass and/or finger euphorbia in one or two rows along the foot of the steep bank.

4.6 Construction of checkdams

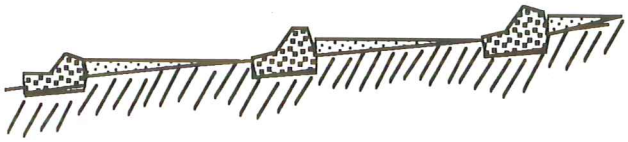
A checkdam consists of a wall across the gully to hold back water and trap sediment. The checkdam has an apron along the gully floor downstream of the wall to absorb the energy of the water spilling over the wall.

Important rules for the construction of checkdams:

- Start at the downstream end of the gully.
- Do not make the checkdam too high. Maximum height of a spillway should not exceed 1m; preferred height is 0.6m.
- Instead of high dams, install several lower ones.
- Make sure that the checkdam is at least 0.3m lower than the level of the ground surface to avoid flooding.
- The crest of a checkdam should not be level but lower in the centre. This so-called spillway often has a parabolic shape so that water will flow in the middle, preventing erosion of the sides of the gully.
- A checkdam must be keyed into the bottom and the sides of the gully to avoid undermining and water cuts around the dam.
- An apron must be installed downstream of the dam to prevent erosion in the water fall. The length of the apron should be 1.5–2 times the height of the dam.

As sediment builds up behind checkdams and eventually reaches the top, the checkdams will act as drop structures. The water flow will then pass down the gully over a series of steps (see Photos 13, 14 and 15, pp.34–35).

Example of steps created by checkdams



Spacing between the checkdams should be such that the slope of the steps is just a few percent to avoid erosion (see Table 2 below).

4.7 Summary

As in all conservation activities, the co-operation and participation of local people is crucial for the success of gully control programmes in the short term, and even more so in the longer term to ensure that essential maintenance work is carried out.

Priorities in gully control work

- Prevention of gully formation through proper land use and management.
- Control/stabilization of small gullies before they become large.
- Improvement of gully stability/capacity to accept a higher flow for it to be used as a waterway.

General procedure for gully control

- Study the gully to understand the cause(s), current active processes, stage of development and problems.
- Determine the responsibility. Who are the implementers of the gully control work?
- Draw up (with concerned people) an appropriate design, including action to counteract the cause of the gully and work on the gully itself (exploit locally available material).
- Prepare a simple cost-benefit analysis to establish whether the control work can be justified. Ideally, costs should not exceed the value of potentially damaged land.
- Advise and assist the people responsible for the implementation of the gully control as designed.

Table 2. Spacing between checkdams of different height in gullies of different slope.

GRADIENT	HEIGHT OF CHECKDAM (metres)								
	0.3M			0.6M			0.9M		
%	WOOD	W/S	STONE	WOOD	W/S	STONE	WOOD	W/S	STONE
4		15			30			45	
6		7.5			15			23	
8		5.2			10			15	
10		4			7.7			12	
12		3.2			6.3			9.3	
14		2.7			5.3			7.8	
16		2.3			4.6		6.7		7.4
20		1.8		3.7		4.5	5.4		6.7
24		1.7		3.1		3.9	4.5		6.1
28	1.4		1.7	2.7		3.4	3.9		5.4
32	1.2		1.6	2.3		3.2	3.3		4.6
36	1.1		1.5	2.1		3.0	3.0		4.4
40	1.0		1.4	1.9		2.9	2.7		4.2

Source: Wenner 1980a and 1984.

Examples of different types of checkdams.

Photo 13. A double-row post-brush dam. (Photo: Arne Eriksson)

Photo 14. Post-stone dam. (Photo: Arne Eriksson)

Photo 15. Stone wall dam. (Photo: Arne Eriksson)

5

LIVESTOCK HUSBANDRY IN SOIL CONSERVATION

5.1 Introduction

In medium to high potential areas in Tanzania, the highly productive land is utilized mainly for crop production. Farmers in these areas use an intensive system for livestock production, normally characterized by small land areas per livestock unit, with intensified fodder production and stall feeding (zero-grazing). Pastoralists and agro-pastoralists generally utilize an extensive livestock husbandry system in low potential areas. The extensive system with free grazing demands large areas where large numbers of animals can graze. They move to the most suitable areas during different times of the year.

In low potential areas with mixed farming, overgrazing is causing severe land degradation. In such areas, advice on livestock management becomes a most important component of a soil conservation programme.

5.2 Some general guidelines for livestock husbandry in land management

In both extensive and intensive systems, sustainable livestock production depends mainly on three factors, *feeding, health* and *reproduction*. This chapter primarily describes how to improve fodder production, since this is important for both livestock production and soil conservation. The description is intended for mixed farming systems.

Generally, improvement of fodder production should aim at increased quantity and improved quality of forage. To achieve good fodder production in a sustainable land management system, the fodder crops should also be utilized as an important component in soil conservation.

The basic strategy is hence to maintain and improve a healthy and productive vegetative cover with grass, legumes and trees. This can only be done if the number of livestock in an area corresponds with the production capacity of fodder. This means that one of the most important principles in livestock management is to control the number of animals according to the carrying capacity of the land.

5.3 Management of grazing areas

Most grazing lands are generally characterized by low and unreliable rainfall, poor and/or shallow soils and high temperatures. The land is most often communally owned without any restrictions on the number of livestock occupying the area.

Controlled grazing

The single most important management factor is to control the number of livestock in an area to its carrying capacity. For grazing control the area should preferably be fenced with live fence (see Chapter 6.5).

Rotational grazing

With rotational grazing the grazing land is divided into a number of smaller areas (paddocks). Each area is fenced and grazed one after the other, in rotation, and thereby allowing rest periods for the vegetation to regenerate. Live fencing should preferably be used to reduce the costs. Also, rotational grazing requires control of the number of animals. If it is done on communal basis, the communal committee organizing the rotational system in the area must be very strong in order to control the number of animals and decide which area to be used.

Pasture improvement and rehabilitation

Rehabilitation of a degraded grazing area with natural pasture should start with closing off the area from grazing animals and thereby allowing natural grasses to establish. Ploughing can be done along the contour to retain and increase water infiltration. A spacing of 3m between the ploughed furrows can be used.

For improvement, the area could also be sowed with suitable fodder species. Usually scratch ploughing (by ox-plough or *jembe*) is needed. If furrows have been ploughed, these can be used for sowing desired fodder species. (More detailed information on grass species is found in Appendix 2.) The number of animals in the area must, after rehabilitation and/or improvement, be controlled to avoid the area being degraded again.

5.4 Fodder production in mixed farming systems

Mixed farming systems are common in medium to high potential areas with intensive use of limited land resources. Shortage of grazing land is often compensated by fodder produced on farm land and harvested in a cut-and-carry system. Fodder production from trees, shrubs, grasses, legumes and crop residues is, under these circumstances, important to maintain a reasonable level of livestock production. This system also promotes control of quality and quantity of feeds to the animals.

Choice of techniques and species for fodder improvement in mixed farming systems depends mainly on the farmers' preferences and physical characteristics of the land. It should be noted that mixed farming with a zero-grazing system can, under certain circumstances and with good management, also be used in low potential areas.

Land management (soil conservation) and fodder production

Described below are different ways and techniques of establishing and/or improving fodder production in a mixed farming system to increase or maintain the total production of the land.

Grass strips

On farm land, natural grasses left to grow on unploughed strips along the contour can produce fodder for the livestock. Unploughed strips left with natural vegetation can also be improved through interplanting with high yielding fodder grasses and/or legumes and trees.

For higher production, vegetative strips of high yielding fodder grasses/legumes and fodder bushes are planted. All such vegetative strips should be harvested with the cut-and-carry method as free grazing can destroy the plants. (See Section 3.2 on *grass strips*.)

Fodder planted on terraces

For the stabilization of terrace embankments, the increased fertility from deposited topsoil and water retained along terrace edges should be utilized for intensive fodder production. To support crop and fodder growth, different types of water harvesting techniques could be utilized. Free grazing should not be allowed on terraced farm land since the livestock would destroy the structures.

Fodder planted along farm boundaries and around homesteads

Fodder grasses and trees can be used to mark boundaries and at the same time produce fodder for the livestock. To avoid destruction of the boundary marks, livestock must be controlled and free grazing prohibited.

Fodder intercropped with food crops

Most fodder grasses and legumes can be interplanted with crops on farm land. Fodder bushes such as *Sesbania, Leucaena* and *Calliandra* are nitrogen-fixing and assist crop growth if interplanted.

Fodder in rotation on crop land

Fodder grasses and legumes (for example, cow pea or velvet bean) can be included in a rotation for fodder and soil improvement.

Fodder plots

An area can be planted and managed for fodder production. This can, for example, be rows of elephant grass (and legumes) interplanted with fodder bushes such as *Leucaena* or *Sesbania*. Fodder plots are normally harvested through the cut-and-carry method.

Crop residues

Crop residue is an important fodder component, especially in drier areas. It could also be used for soil improvement (compost manure) or erosion control (trash lines/mulch). How the crop residues are used depends on farmer needs and priorities.

Manure

Animal manure is a cheap and effective fertilizer. Manure applied on farm land or used as compost manure improves soil fertility and enhances high yields of crops and fodder. The collection of manure is easy with a zero-grazing unit.

Agroforestry

A wide range of agroforestry options are discussed in Chapter 6.

For improved fodder production, leguminous trees and bushes can be planted on terraces, around homesteads, as boundary marks or interplanted in a fodder plot that can assist production of fodder grasses. Nitrogen-fixing fodder trees, for example *Calliandra, Sesbania* and *Leucaena*, can increase crop production and, at the same time, improve forage quality and provide fuelwood.

5.5 Fodder establishment techniques

Planting materials are produced from seeds, cuttings or root stocks/root splits. Described below are some general aspects for fodder establishment. More detailed information on the most common fodder grasses, legumes and trees is found in Appendix 2.

Land preparation

Generally, land preparation for fodder establishment is the same as for other crops. The land requires clearing of undesirable vegetation by ploughing or digging with a *jembe*. Ploughing should be done deep enough to create favourable conditions for root development. For establishment of grass and legumes propagated by seeds, a fine seed bed is needed.

Propagation by seeds

Seeds may be broadcasted or drilled in rows. Drilling is generally more suitable for controlled seed rates and depth, weeding and harvesting.

Dormancy (inactive phase) of seeds can be broken by treating the seeds with hot water. Seeds that need hot water treatment are placed in a bag and soaked in the water for 1–2 minutes. The water should have a temperature of 70–80°C. A simple way is to heat water until the first bubbles appear in the bottom of the container. Remove the water from the heat and soak the seeds. Seeds should thereafter be spread out on a clean surface to dry under the sun. Plant the seeds directly the following morning.

Seed dormancy could also be broken by rubbing the seed-head with sand or sand paper. This process is known as *scarification* and can be used for some specific species.

REMEMBER!

Immediate sowing of the seeds after treatment is necessary for good results. Seeds take 5–14 days to germinate after sowing.

Oversowing on existing vegetation involves little labour but tends to result in poorer/slower establishment. It requires more seeds per land unit.

Depending on climatic conditions of the area, sowing should be done at the on-set of the rainy season. Consult successful farmers and/or agricultural specialists to determine the appropriate seed rates and timing for sowing in a specific area.

Planting (vegetative) materials

Planting material is produced from seeds, cuttings or root stocks/root splits. There is generally a better survival rate from cuttings and roots rather than seeds in low potential areas with low soil moisture.

Root stocks and root splits

A *root stock* is a fully grown plant that is removed with the roots and stem. The leaves are removed and the stem is trimmed down before planting. It is also possible to plant root stocks without removing the leaves. Good examples are elephant grass and Guatemala grass.

A *root split* is a young shoot arising from the parent plant. The whole shoot including the root is removed from the parent plant. The leaves are thereafter removed, and the shoot is pruned before planting. The split could also be planted with the leaves. Examples of plants propagated from root splits are Guatemala grass and *Setaria*.

Dig holes suitable for placing the stock/splits. Cover the whole plant with soil after planting (except the trimmed stem). Firm the soil so that the stocks/splits stand upright.

Stem cuttings

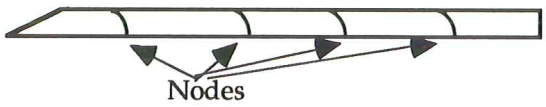
Some fodder plants can also be propagated by cuttings. The use of cuttings is generally the easiest way to propagate fodder plants. One of the most common grasses in Tanzania that can be propagated with cuttings is elephant grass. *Desmodium* spp and *Gliricidia* are also used. The soil should be smoothed by ox-plough or *jembe* before planting with cuttings.

To get cuttings, the mother-plant should be let to overgrow and produce a hard stem. The stem is cut and the leaves are removed. From the bare stem, cuttings with at least 3-4 nodes are prepared.

Procedure for elephant grass

This example describes how cuttings of elephant grass are planted on terraces (also see Photos 16 and 17, p.42).

1. Construct the terraces where the grass shall be planted. No further land preparation is needed since planting is done in the soft soil on the constructed embankment.
2. Collect cuttings from overgrown elephant grass. The grass should be at least 2m high.
3. Remove the leaves and prepare cuttings with 3-4 nodes on each.



4. Stick the cuttings into the soil along the terrace. Cuttings are placed into the soil at an angle with the top above the soil surface. (Cuttings can in some cases also be planted flat just under the soil surface.)

The cuttings should be planted in a zig-zag manner in two rows on the sides of the embankment. The spacing should be approximately 20–30cm and the width between rows approximately 30–60cm. The spacing depends mainly on the width of the terrace embankment and desired density of the planted grass. New shoots will sprout from the nodes of the cutting.

Elephant grass can reach up to 2–3m in height. The grass should be harvested at a height of 1–1.5m to achieve highest nutrition value and regrowth. Cut the grass approximately 10cm from the ground.

A creeping legume such as Silver Leaf *Desmodium* could be interplanted with elephant grass. The legume will climb on the grass and can be harvested together with the grass to further increase the nutritional value.

Fodder bushes like *Sesbania*, *Leucaena*, and *Calliandra* can also be planted along the terrace with Elephant grass. If direct sowing of fodder bushes is practised, it is advisable to plant the trees earlier since elephant grass is relatively aggressive.

Fodder management and harvesting

Weeding

Weeding should be done as early as possible after planting. Do not leave weeds to flower since the density of weeds will increase in the next season. If land is not intensively utilized and weeds do not adversely affect crops by competition, it is often better to simply slash weeds and use them for mulch.

Fodder harvesting

Generally, harvesting should be done before the flowering stage. Waiting until fodder grasses have

produced seeds will reduce their feed value considerably. In mixed farming systems, zero-grazing with a cut-and-carry system is generally recommended. If direct grazing is practised, it must be controlled with, for example, rotational grazing. Tall and succulent grasses like elephant grass, Guatemala grass and *Setaria* can easily be uprooted when directly grazed and are therefore not recommended for direct grazing

Replanting

Good management can extend the lifespan of the fodder, but fodder must be replanted to maintain high production. Replanting demands planning and timing to ensure that high fodder production is maintained.

5.6 Zero-grazing

A zero-grazing system consists of a permanent cow-shed and intensive fodder production harvested by the cut-and-carry method. Restricting grazing from crop land and producing fodder on conservation structures promote livestock production and good land management. The major advantages of zero-grazing can be summarized as follows.

- Breeding and animal health is under good control.
- There is efficient use of fodder and crop residues.
- There is no excessive trampling of crop land or animal tracks which can cause gully erosion.
- High production per animal occurs with both upgraded cattle and good local breeds.
- Collection of manure is easy and convenient for immediate use in the farm.
- Manure can be used for biogas as a cheap source of energy.
- Zero-grazing frees children from herding so that they can go to school.

Although zero-grazing in many respects is productive and efficient, it is labour-intensive in terms of fodder and water collection. This can restrict the number of animals kept. Permanent water must be available within a reasonable distance. Good management of fodder production is needed to achieve high output from the livestock.

Establishment of a zero-grazing unit

Establishing a zero-grazing unit demands long term planning of fodder production, water availability, investment to construct a cow-shed and investment in cattle.

Fodder production and water availability

Reliable fodder production must be established on the farm. The quantity of fodder needed depends on the type and number of cattle. Cross- and pure-breed cattle demand more water and fodder (both in terms of quantity and quality) than local cattle.

Investment costs

Construction of a zero-grazing unit is assumed to be a big investment. This may be true if one considers costs of purchasing pure- or up-graded breeds and construction materials like cement, iron and timber. The construction costs can be cut by using cheap locally available materials and by choosing productive local cows which can increase milk yields under good management.

Selection of cattle

Highest production would be achieved with cross-breed/pure-breed cattle, especially in high potential areas. This, however, means a high investment cost which many farmers cannot afford. Improved cattle, especially pure-breed, also demand more attention in terms of animal husbandry. A cheap method to produce upgraded cattle is to select good local cattle for breeding with a cross- or pure-breed bull. More information on upgrading cattle can be found in RSCU/SIDA Report No 8. *Improving Livestock Production in Babati District* (1993).

Establishment of a cow shed

The investment costs for establishing a cow-shed depend mainly on the material used. It is advisable to utilize as much locally available material as possible to reduce the construction cost (see Photo 18, p.43).

There are certain important factors to be considered when constructing a cow-shed.

The unit should be located on elevated and well-drained land close to a permanent water source. It should also have enough space for possible expansion of the unit.

Photo 16. Cuttings collected from overgrown elephant grass. (Photo: Per Assmo)

Photo 17. Planting cuttings of elephant grass along a constructed channel terrace. Mukulat Division, Arumeru District. (Photo: Paul Rimmerfors)

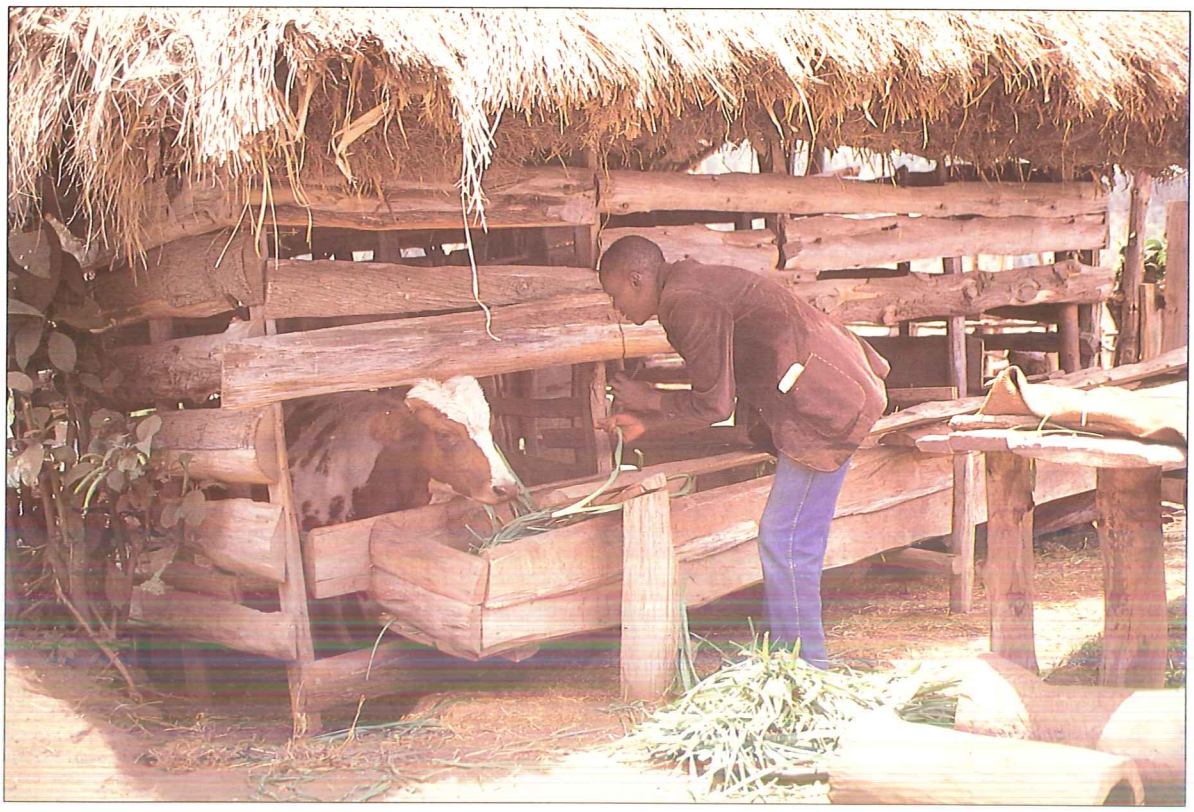


Photo 18. A farmer feeding his livestock using zero-grazing. Observe the local material used for the cow-shed. Mukulat Division, Arumeru District. (Photo: Charlotte Thege)

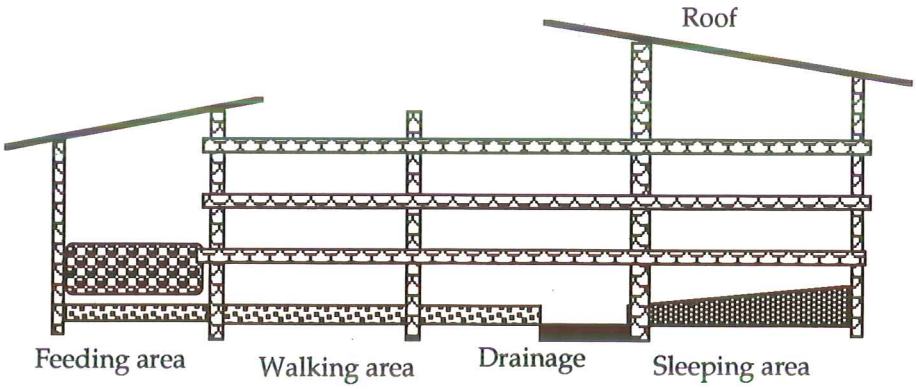
The shed should be built using cheap and locally available materials. It should be simple and well ventilated. Grass (or iron sheets if available) can be used for roofing. If possible, catch the rainwater from the roof to be used as drinking water for the animals. To allow light in, no roof in the drainage and walking area is needed.

The floor in the sleeping pen should be dry and raised, preferably by using compacted soil. There should be a pole tied across the sleeping pen (neck bar) to prevent animals from soiling the pen. Feeding and water troughs should be roofed. The walking area may be made of concrete or flat stones to ease cleaning.

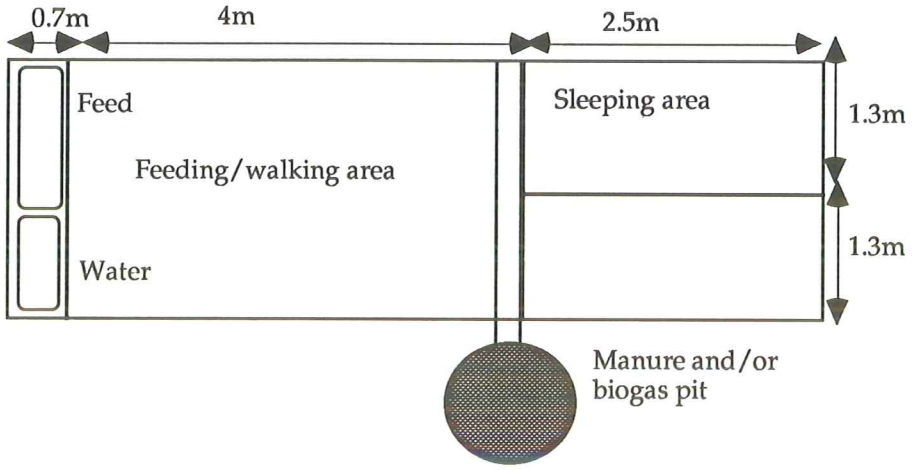
A calf-pen can be built next to the cow-pen. All sides should be covered to protect the calf. The floor should be raised and slanted for easy drainage of urine and dung. It should have separate feeding and drinking troughs. A manure pit should be dug on the lower part of the unit for easy collection of manure.

Below is an example of a cow-shed. The dimensions (p. 44) could be slightly modified to suit different conditions.

Side view



Top view


0.7m
4m
2.5m
Feed
Feeding/walking area
Water
Sleeping area
1.3m
1.3m
Manure and/or
biogas pit

6

AGROFORESTRY IN SOIL CONSERVATION

6.1 Introduction

This chapter provides a general description of simple planting and management techniques for agroforestry trees. A list in Appendix 1 presents names, description, uses, propagation, seed treatment and management for some of the most common tree and shrub species used in mixed farming systems to enhance farm production.

What is agroforestry?

The integration of trees on farm land is an old traditional agroforestry practice used in many parts of East Africa. *Agroforestry* can be defined as a land use system in which trees or shrubs are grown together with crops and/or livestock on the same piece of land. The system can be mixed in a spatial arrangement or in a time sequence. Proper management of trees and shrubs is essential if the interaction between the components is to be positive and thus beneficial to the farmer.

Why agroforestry is important

The integration of trees and shrubs in a farming system can improve the use of natural resources on a sustainable basis. Agroforestry offers solutions for rural people to meet most of their daily needs in terms of fuelwood, poles, shade, fodder, food and timber. Agroforestry also contributes to soil conservation, reduces soil loss and improves soil fertility. Below is a summary of the products and service functions of multipurpose agroforestry trees.

Fertility improvement and soil conservation

Crop and fodder production can benefit from trees through fertility improvement. When leaves, twigs and roots decompose, humus and minerals are released. Some trees are nitrogen-fixing which can help to sustain the growth of associated food crops. Soil moisture conservation/retention is also increased through the organic matter added to the soil, improving the ability of the soil to absorb and retain water. This results in increased crop growth.

Roots hold the soil together and thus reduce erosion. This is particularly important with trees grown along contours. Tree litter and tree crowns may reduce the erosivity of falling raindrops (splash erosion). Trees can act as wind breaks, protecting the land from wind erosion. Trees can also provide shade for livestock and bare soil.

Fodder

Trees supply fodder for livestock, especially during the dry season when other sources of fodder are scarce. Fodder can be harvested through pollarding or coppicing, or alternatively, livestock can browse directly on trees and shrubs.

Wood products

An important product from trees is of course wood. This includes the production of fuelwood (including charcoal), poles and timber for construction and fencing material. Wood products can also be sold to generate cash income.

Food

Fruits are often highly nutritious. Trees can produce a variety of food products for domestic use or sale. These include fruits, nuts and edible oils.

Other uses

Apart from the uses mentioned above, trees can also provide a number of other products for do-

mestic use or sale, for example, oils, gums, waxes, dyes and fibres. Trees can also provide important products for medical use.

Other economic and socio-economic advantages

Agroforestry can increase the total production per unit area of land. Tree products can often be obtained throughout the year, providing job opportunities and regular income. Some tree products can be obtained in the agricultural off-season. (When opportunities for other kinds of plant production decline.) Various components or products from the system might be used as input to other farming activities (for example, nitrogen-fixing trees, green manure), thus reducing the need for costly fertilizers.

Constraints of agroforestry systems

There are some limiting factors that must be considered when implementing agroforestry systems.

Ecological constraints

Tree species have specific ecological requirements which means that trees can only grow under certain conditions.

Pest and diseases

Both trees and crops can be affected by pests or diseases which may hamper production.

Competition with food crops and/or livestock

There is often some competition between trees and food crops, especially in low potential areas. Competition can be minimized by proper management of trees and shrubs, for example, pollarding to reduce shade. Livestock can also sometimes conflict with tree growing, especially in areas where free grazing is practised and the livestock population is high.

Competition for land

Land shortage in high potential areas limits the number of trees that can be grown on each farm. Farmers fear that the trees would compete too much with crops on small farms and sometimes use this as an argument against integrating trees.

Long-term planning

For good availability of seeds and/or seedlings, long-term planning is needed, including development of small tree nurseries along with replanting and maintenance.

Land and tree tenure

There is generally a connection between land ownership and the willingness to make long term investments, such as tree planting. Unclear ownership of land, laws that restrict harvesting/cutting of trees and taxation of tree harvesting are factors that restrict farmer interest in tree planting.

Gender issues

Land tenure and tree planting is a gender sensitive issue. Since men are heads of families in most societies in Tanzania, they are responsible for supervision and decision-making. Decisions such as what crop to plant, where to plant and harvesting of tree crops are very often the responsibility of men. In some societies there are traditional beliefs and taboos; for example, women are not allowed to plant trees.

6.2 Selection of agroforestry trees and shrubs

There are four main factors to be considered before recommending tree species to farmers:

- *Farmer needs and preferences.* These include fuelwood, poles, fruits, fodder, timber, soil fertility improvement.
- *Climate.* Most tree species can only grow in specific ecological zones.
- *Site.* Site should be chosen for soil type, water availability, water logging, occurrence of fires etc.
- *Socio-economic factors.* These include taboos and beliefs.

It is of course difficult to find a tree that exactly matches farmers' needs and preferences. Desired characteristics from the list below could be a guideline for selection. Chosen species should be:

- multipurpose, that is, have more than one product and/or use;
- fast growing to provide high biomass production;
- deep-rooted to minimize competition for water and nutrients with agricultural crops;
- capable of coppicing, that is, having the ability to grow back after cutting, thus eliminating problems of replanting;

- palatable and nutritious to function as fodder for livestock;
- nitrogen-fixing to improve soil fertility and increase crop production;
- non-competitive with crops, if intercropped on farm land;
- having a light crown to avoid shading of agricultural crops, or a dense crown, if shade is desired;
- easy to manage in order to minimize labour and costs.

6.3 Establishment of agroforestry trees and shrubs

More detailed information on some of the most common tree species is found in Appendix 1. There are basically four techniques used for tree establishment:

- Direct sowing
- Cuttings
- Seedlings established from a nursery
- Wildlings

Seed collection

Relying on seeds from outside, through buying or distribution from central nurseries, is not a viable solution. Local collection of seeds can easily be done by simply observing flowering and fruiting of various desired tree species to know when the mature seeds are available.

Collect seeds which are clean, undamaged and free from pests and diseases. By collecting seeds from a known source of good quality trees, the problems of diseases and poor production can largely be avoided.

- Collect only mature seeds for good germination.
- Collect seeds from trees that look like the ones wanted.
- Collect seeds which have not been affected by insects. It is preferable to collect seeds from the tree and not from the ground.

Extract collected seeds from pods, cones or fruit and allow to dry. Oily seeds, or seeds with soft cover should not be dried and stored but sown immediately. Seeds with hard covers can usually be stored. Store seeds in a clean, dry, cool place protected from insects and rats.

Pre-treatment of some seeds can increase the germination rate. This can be done by soaking the seeds in hot water for a short period, or cold water for a longer period.

Direct sowing

Direct sowing has the advantage of being cheap, compared to costs for labour and investments needed if raising seedlings in a nursery. Direct sowing should be done if seeds are plentiful and inexpensive as the survival rate is lower than that of seedlings raised in a nursery. There is also a risk that seeds can be washed away by rain or eaten by insects or animals.

Land preparation

The land should be cleared and weeded. The soil surface should be smoothened to enhance seed germination.

Sowing

How the seeds are sown depends on species. Light seeds can be spread over the soil or covered with a very thin soil layer. Larger seeds are normally planted with 2–3 seeds per hole, if germination is known to be good, or 3–5 seeds if germination is poor or not known. Spacing depends on the intended use of the trees.

Direct sowing is always done in the beginning of the long rains. Examples of trees that can be raised by direct sowing include *Leucaena* spp, *Sesbania* spp, *Croton megalocarpus* and *Calliandra calothyrsus*.

Establishment by cuttings (vegetative propagation)

Some trees and shrubs have the ability to regenerate quickly from sections of stems or branches, generally called *cuttings*, that develop roots when planted in the soil. Cuttings can be propagated in nurseries or directly planted. The use of cuttings is good for growing identical trees with desired characteristics. Cuttings also have faster initial growth rates than seedlings.

Preparations of cuttings

The tree from which the cuttings are taken should be healthy and free from diseases. It is recom-

mended to maintain a few easily accessible trees to enhance the availability of planting materials.

After cutting, the stem should be cleared of leaves and flowers as these may increase loss of water by evaporation. The length of the cutting ranges normally between 30 and 45cm. It is important to include at least three nodal points. When planting, at least two nodal points should be buried in the soil.

Cuttings must be planted with the top facing up. To identify the top of the cutting, make a slant cut 1–1.5cm above the node and a straight cut in the bottom. The slant cut shows the top while the bottom straight cut shows the bottom when planted.

Land preparation

For direct planting of cuttings, the land should be smooth to enhance regeneration. The soil should be prepared by deep ploughing at the onset of the rains. This can be done by hand hoe or ox-plough. Loose soils with good infiltration capacity are preferred for direct planting of cuttings.

For nursery planted cuttings, care must be taken to ensure adequate temperature and aeration at the rooting end of the cutting. Adequate temperature can be achieved by preparing a shade to avoid direct sunlight onto the cuttings. The shade also reduces water loss by evapotranspiration. Ensure good drainage in the pot/container (open underneath) and a proper mixture of loose and well drained soil.

Planting

The cutting is placed with the straight cut into the soil. At least two nodes should be in the soil. Cuttings must be well watered (but not waterlogged) until the roots sprout. Examples of trees and shrubs which can be propagated by cuttings are *Morus alba, Gliricidia sepium, Euphorbia* spp, *Ficus* spp and *Commiphora* spp.

On-Farm nurseries

Tree seedlings can be raised in two different ways in nurseries. They can be sown in a seed-bed and planted directly into the field, or they can be sown in a seed-bed, pricked out in pots and thereafter planted in the field.

Seedlings raised in containers need more labour input but generally have a higher survival rate in the field. Establishment of the nursery and the initial sowing of seeds in the seed-bed is basically done in the same way for both directly planted seedlings and seedlings transplanted into pots.

Nursery establishment

A nursery is a safe place where seedlings are raised and cared for until they are ready to be replanted in the field. The basic requirements for a small nursery are adequate water supply and labour, since seedlings demand frequent watering and weeding. The nursery site should preferably be inside the homestead.

The nursery consists of a *seed-bed* where seeds are sown and protected before out-planted in the field (Photo 19). A protected area directly connected to the seed-bed is also needed if seedlings are transplanted in pots before out-planting in the field. The area should be cleared from weeds and slightly graded to avoid waterlogging under the seed-bed and pots. The nursery should have a reliable source of water.

Seed-bed preparation

Seeds should be sown in a seed-bed before transplanted into pots, or straight to the field. A seed-bed can be made from wood, bricks, banana stems or bamboo stems. (Use whatever material is locally available.) The size of the seed-bed can vary depending on the desired production capacity. The height should be 20–30cm.

The seed-bed is filled with good fertile topsoil, not too clayey or sandy. The nursery soil should be approximately 15cm thick. After the seed-bed is filled, the soil should be firmed lightly.

Soil mixtures

Usually, fertile topsoil is sufficient for production of most tree seedlings. The soil should not be too wet and sticky. In areas with clay soils, sand could be incorporated together with farm yard manure to achieve a suitable soil mixture. The farm yard manure should not be too wet, and the decomposition should have been completed. If the soil in the location is very poor and infertile, the ratio of farm yard manure can be increased.

The same soil mixture is used for both the seed-bed and the pots. The components are thoroughly mixed and thereafter brought to the seed-bed or put into pots.

Photo 19. A small on-farm nursery in Sakila village, Arumeru District. (Photo: Per Assmo)

When to sow

Planning and timing when to raise seedlings in the nursery are important as seedlings demand a certain growing period before they can be out-planted in the field. Generally, seedlings are best out-planted in the field in the beginning of the long rains. The growing period depends on the species and local climate conditions. *Grevillea robusta* takes approximately six months in the nursery before seedlings are ready for planting in the field. Fast growing species like Sesbania and Leucaena need two to three months.

Seed sowing

Seeds can be placed in furrows or in individual holes. Larger seeds should have a spacing of 3–5cm to avoid competition. Smaller seeds can be planted in furrows which are 10cm apart, at a depth equal to the size of the seed. Very small and light seeds (e.g. *Casuarina*) can be mixed with sand or sawdust and broadcasted (spread on the top of the seed-bed). This is to avoid sowing too many seeds on the same spot.

Cover the seeds with soil and firm lightly. Water carefully and cover the seed-bed with leaves of grass to conserve moisture. Remove the cover when seedlings appear. Line sowing is advisable for seedlings to be directly planted in the field. Seedlings for pricking out in pots can be sown by broadcasting.

Out-planting seedlings directly from the seed-bed to the field

The method of out-planting seedlings directly to the field is only suitable in medium to high potential areas. In drier areas potted seedlings should be utilized. Some species like *Grevillea robusta* have a higher survival rate if raised in pots.

Management of seedlings in seed-bed

The seedlings need watering, weeding, root-pruning and protection against sun and animals.

Shading is done by constructing a light shelter on the seed-bed. It should be about 75cm high, with a roof of grass, straw or leaves.

Watering should be done twice per day in the first two to three weeks. Thereafter watering can gradually be decreased to 4–5 times per week, depending on the climate in the location. Water the seedlings in the morning and evening when the sun is not too hot.

Weed regularly and thin seedlings to an in-row spacing of 5cm.

Root pruning helps the seedlings to grow stronger and healthier. First pruning is done when seedlings are approximately 5cm tall. Use a sharp knife or wire and carefully cut off the roots under the seed-bed. Continue root pruning approximately once a month. Water the seed-bed before root pruning. Careful watering and shading are important the first days after root pruning.

Before out-planting in the field the seedlings must be *hardened* during the last month. Gradually remove the shade until the seedlings are exposed to full sunlight. Reduce watering to 4–5 times per week and gradually increase root pruning to once a week.

Out planting in the field

Before out-planting in the field, water the nursery bed and remove the frame around the seed-bed. Use a sharp *panga* to cut the seed-bed into one soil-block for each seedling. Plant the seedlings in holes that have been prepared in advance. Place the seedling with the soil-block in the hole and firm soil around it. Initially the seedlings should be weeded and protected from browsing and trampling.

Transplanting seedlings from seed-bed to pots

Management of seedlings in seed-bed

Transplanting of seedlings from the seed-bed to pots is done when the seedlings are still small. The seedlings need the same management in the form of watering, weeding and protection against sun and animals as described above.

Pots

Apart from polythene tubes (plastic pots), different types of material like bamboo, banana leaves and discarded tins can be used to make pots. Pots should have holes in the bottom to allow drainage of excessive water. Drainage, aeration and fertility are ensured by proper soil mixtures.

Pricking out

Pricking out is the transfer of the seedlings from the seed-bed to the pots where they are managed until ready to be planted in the field.

The procedure is as follows:

- Fill the required number of pots with a soil mixture as described above. When filling, the lower third of the pot should be compacted rather firmly to make sure the soil does not fall out easily. The upper two-thirds is compacted gently so that roots can develop easily.
- Prick out when the seedlings are still small, generally when they have developed their two first leaves. Use a small stick or a pencil to make holes in the soil of each pot. Make the hole deep and wide enough to accommodate the seedling. The hole is closed by gently pressing the soil around the seedling with the fingers. The pricking out should be done under shade.
- Water the seed-bed thoroughly a day before transplanting the seedlings. Use root pruning so that the seedlings can be easily removed. Remove the seedling by holding the leaves and not the stem. If necessary, trim off the roots, especially the tap root if it is too long.

Management of potted seedlings

After pricking out, continue watering the seedlings twice a day for the first week. Watering could later be reduced to 3–4 times per week. To harden the seedlings, gradually reduce watering before out-planting in the field to 1–2 times per week. Hardening will minimize transplanting shock in the field. Water thoroughly before out-planting the seedlings in the field.

It is necessary to construct a shade above the potted seedlings during the first weeks after pricking out. Construct a shelter approximately 75cm above the pots. When the seedlings grow and become more resistant, shading is gradually reduced. For the last months in the nursery, seedlings should be exposed to full sunlight.

Root pruning should be done every 2–3 weeks until the potted seedlings are ready to be taken to the field.

Planting

Water the potted seedlings before transporting them to the planting site. The seedlings should be transported in the pots which are removed just before planting. Plant the seedlings in holes that have been prepared in advance. Place the soil-block in the hole and firm soil around it. Planted seedlings should be protected from browsing and trampling by livestock.

Transplanting wildlings

Trees and shrubs regenerate naturally through dispersal of seeds. These wild seedlings (wildlings) can easily be collected and re-planted on the farm.

They should be carefully uprooted, keeping a good block of soil around the roots, and planted in the same way as seedlings taken from a nursery.

6.4. Tree management

Once the trees/shrubs are established in the field, they must be properly managed to maximize production and limit competition between trees and crops. This can be done in various ways.

Pruning

Pruning is the cutting of branches to obtain a tree of desired shape and to maintain a balance between fruiting and vegetative growth. Pruning should start while the trees are young, and side pruning is normally done starting from the lower side of the crown, moving upwards. Larger trees are pruned to minimize shade on the crop and to harvest branches for fuelwood, mulch and fodder. Leaves and small twigs should, if possible, be incorporated into the soil to increase soil fertility.

Pollarding

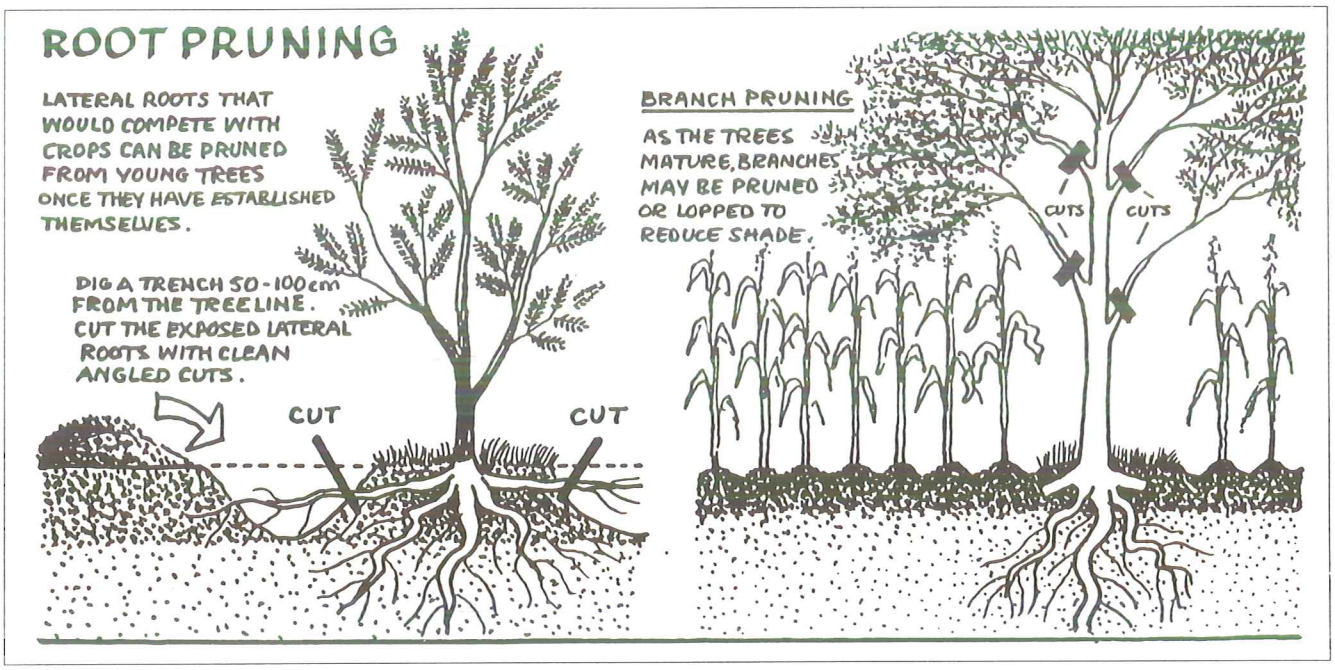
Pollarding is the extensive cutting back of the tree crown (at a minimum height of 2–3m from ground level) to harvest branches and leaves and to stimulate new growth and a better formed and productive crown. Pollarding works well with species like *Grevillea robusta, Acacia albida* and *Bridelia micrantha.*

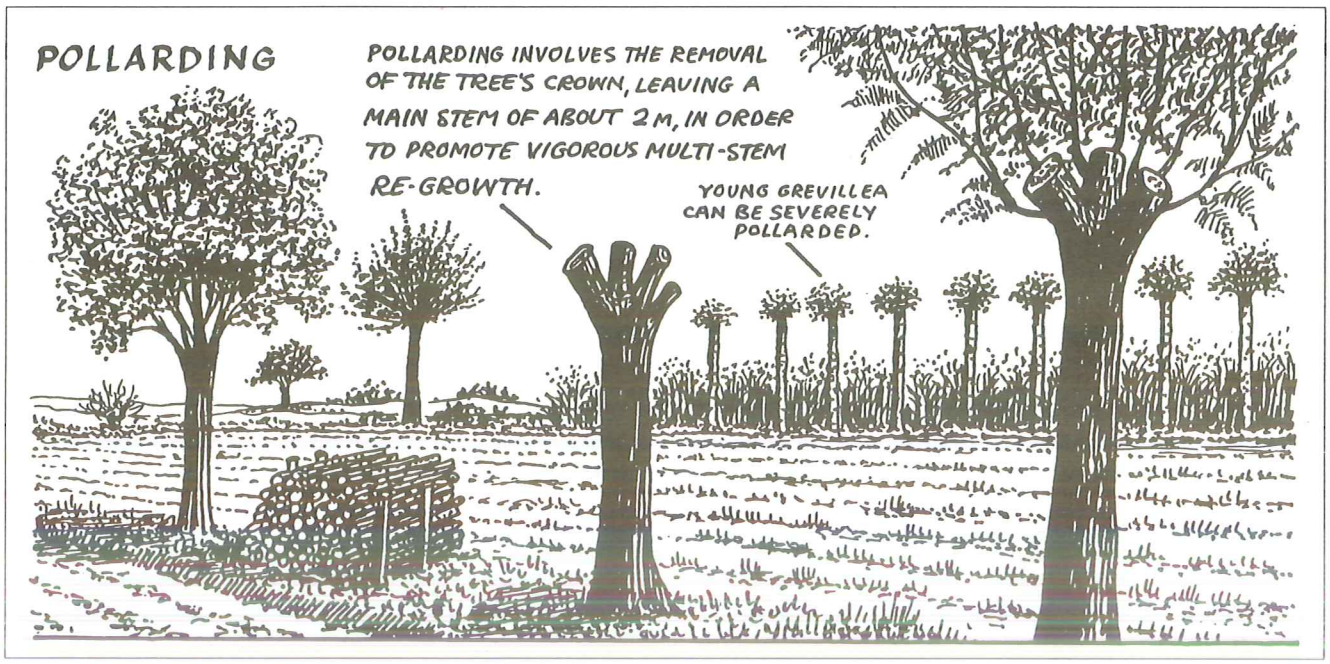
Coppicing

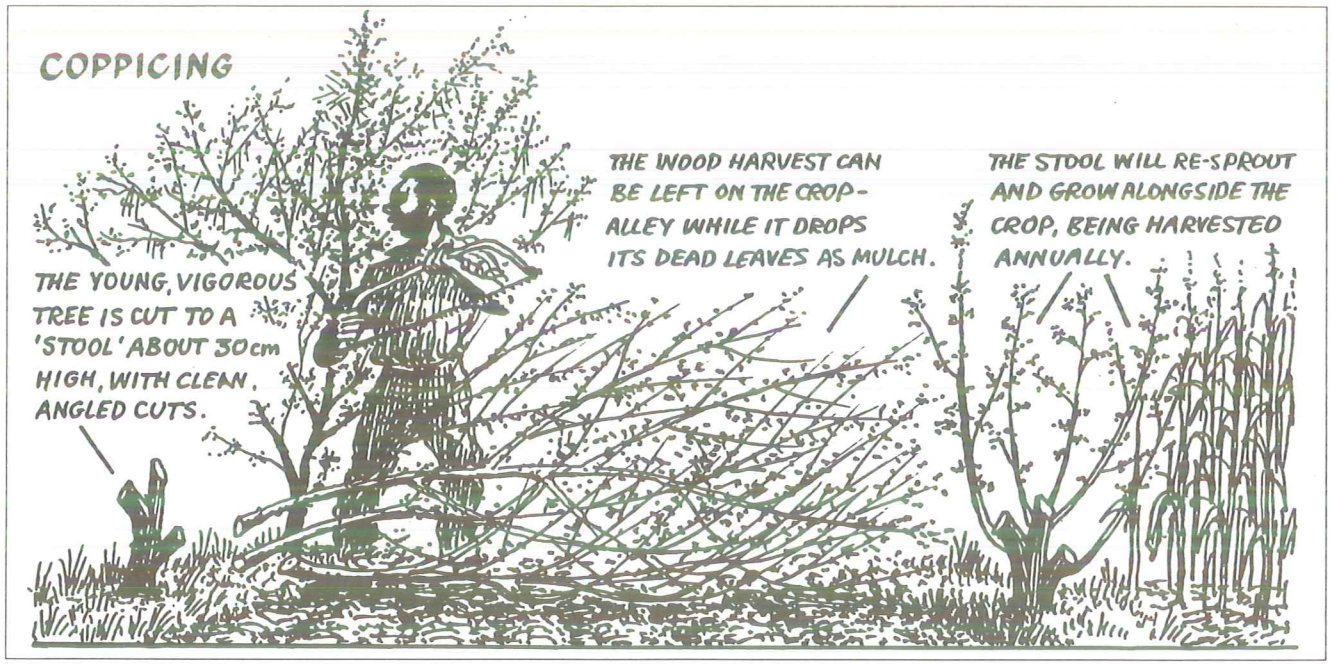
Coppicing is the cutting back of the tree 10–50cm from the ground to stimulate production of new shoots.

- The first coppicing should not be done until trees are 3–4m high to allow the root system to become well established. If shading becomes a problem before then, the lower branches should be pruned.
- Repeated coppicing could be done when there is too much shading of crops or when the farmer wishes to harvest branches for wood, fodder or poles. Coppicing should be done with a slant cut.
- For most species, coppicing should not be done at the peak of the hot, dry season, or at the peak of the wet season.

Tree species which coppice well are *Senna siamea, Senna spectabilis, Calliandra calothyrsus, Leucaena* spp and *Eucalyptus* spp.







6.5 Examples of trees for growing on farm land

Trees on contour lines and terraces

Trees can be interplanted on contour lines and terraces in the farm land. The most common trees for this purpose are nitrogen-fixing fodder trees and shrubs which assist in stabilizing conservation structures, provide nitrogen fixation to assist crop production and produce fodder for livestock or mulch. The branches can also be used for fuelwood.

Trees can be planted on the lower (low rainfall areas) or upper side (high rainfall areas) of terrace embankments. Spacing for shrubs should be dense (0.1–0.5m). In medium to high potential areas it is advisable to establish the trees through direct sowing.

Management of trees in crop land is important. Some tree species might need pollarding or pruning to avoid shading the crop. Fodder shrubs such as *Leucaena* can become a weed if not harvested regularly.

Examples of some tree species that can be planted along contours in cropped fields are *Sesbania sesban, Leucaena diversifolia, Gliricidia sepium, Calliandra calothyrsus, Tipuana tipu* and *Grevillea robusta.*

Trees on boundaries

Trees and shrubs planted on boundaries and around homesteads can, apart from marking boundaries, provide useful products like fruits, fodder and fuelwood, and can also act as wind breaks. In combination with a live fence, a boundary plantation restricts cattle from entering fields and homesteads. It is cheaper and more durable than any constructed fence. Trees in a single line can be densely planted (0.3–1.5m for trees and 0.1–0.5m for shrubs).

Thorny trees and shrubs could be useful for live fences in areas with high livestock pressure. Trees for live fences should be easily established, relatively fast growing and have a long life span. Hedges should be properly trimmed to remain dense but not too wide.

Examples of tree species that can be used for boundary planting include *Acacia* spp, *Senna siamea, Caesalpina decapetala, Cassia spectacilis, Croton megalocarpus, Calliandra calothyrsus, Croton megalocarpus, Dovyalis caffra, Gliricidia sepium, Grevillea robusta, Morus* spp and *Psidium guajava.*

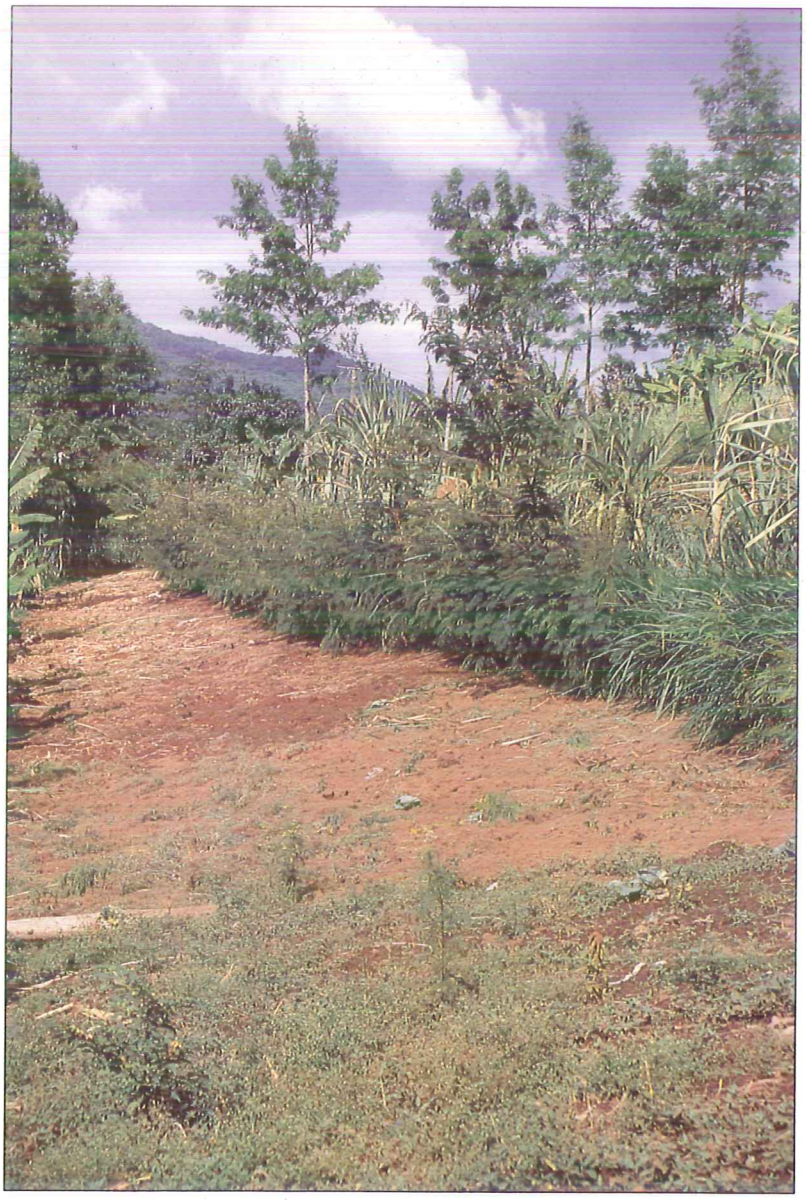


Photo 20. Example of trees (*Leucaena* and *Grevillea*) planted on terraces and along boundaries. Moshono Division, Arumeru District. (Photo: Per Assmo)

7

EXTENSION FOR SOIL CONSERVATION

7.1 Extension services in Tanzania

The main objective of the extension service is to provide recommendations for the farming community to improve and maintain agricultural production on a sustainable basis. A leading principle is that rural people's knowledge should be incorporated with the knowledge of trained extension personnel from different disciplines. This process has to be simple enough to enable extension staff at sub-district levels to implement the activities with little or no support from specialists. In fact, the ultimate goal is to let the local people plan and implement development activities themselves, with extension staff as the participants facilitating the process. As most farmers are practising a diversified farming system depending on crops, livestock and forestry for their income and household production, extension services should be co-ordinated and integrated between departments.

Catchment approach

A *catchment*, also called *watershed*, is a geographical term for the highest point from which water is shed on either side to different drainage systems. The term *catchment*, used for soil conservation in this description, means a unit of land which drains run-off water to a common point, for example, a mountainside that drains water into a river or lake. A *sub-catchment* is a smaller part of a larger catchment and can, for example, consist of a hillside or a valley along a mountain slope.

The objectives and techniques used in a catchment approach may differ between projects, districts and even catchments. However, there are two main reasons for using a catchment approach to define a working area for soil conservation. Firstly, conservation of a catchment/drainage area enhances efficient use of land resources. Conservation of the catchment can also protect water resources, moderate floods and reduce silting up of dams, both within and outside the catchment. Secondly, with the catchment approach, land with a more uniform farming system is selected to implement effective and sustainable soil conservation measures. This enhances community-based solutions, which are many times necessary to improve agricultural production in an area. Catchments or sub-catchments are generally the most suitable areas in which to initiate conservation activities.

If soil conservation extension work is to be successful, it is a good idea to select an area where the community has a common interest in conservation.

Individual approach

Scattered farming communities, or a landscape structure without a defined catchment, might need a different extension approach. It could in such cases be necessary to initiate soil conservation individually on each farm.

7.2 The SCAPA approach

This section describes how SCAPA utilizes one model of catchment approach to train and assist the farming community to integrate soil conservation in their farming practices. The project utilizes different ways to implement conservation

activities, depending on physical conditions, cultural practices and resources available. Each catchment area community can therefore have a separate approach, suitable to local conditions, needs and priorities.

Remember that some points discussed in this text may not be valid; they may need to be modified to suit the local conditions in a particular area.

Arumeru District, where SCAPA operates, can generally be divided into high and low potential areas.

High potential areas are characterized by small farm holdings (0.5–1.5 hectares) often situated on sloping land in hilly mountain areas. Most land is used for crop production, and zero-grazing systems are common. In these areas it is appropriate, and most often necessary, to work with a catchment approach to facilitate the activities. A catchment can include up to a hundred farms.

Low potential areas are characterized by larger farm holdings (1.5–10 hectares) situated in a rolling undulating landscape with gentle slopes. Generally free grazing of livestock is practised in these areas. The catchment approach can also be used under these circumstances, although some changes are required to suit the problems and needs in low potential areas. The number of farmers in each catchment is generally smaller compared to high potential areas. With scattered farms it could also be necessary to use an individual approach and assist each farmer separately.

Integration

A district team, called the Project Co-ordinating Team (PCT), is the co-ordinating body of the project. The PCT includes the following staff:

- Livestock Officer
- Agriculture Officer
- Horticulture Officer
- Soil Conservation/Land Use Planning Officer
- Forestry Officer
- Community Development Officer

The PCT is an integrated team where all members are trained to advise on soil conservation as an integral component in crop, livestock, (agro)forestry and community development. The main tasks of the PCT are to execute project activities, such as training of extension staff and farmers, supervision of extension staff and organization of village soil conservation committees. Each team member is responsible for all activities and supervision in several project areas.

SCAPA provides training on soil conservation and agroforestry to extension staff from various disciplines. The extension staff shall thereafter, with supervision and technical assistance from the PCT, initiate conservation activities in their respective village/catchment area. In the initial phase, farmers and extension staff are assisted with equipment for soil conservation, planting material and tree seedlings.

Farmers' participation

It is a SCAPA policy that the farming community take the responsibility for and actively participates in planning, implementation and maintenance of soil conservation activities. The main aim is to create awareness and skills among the farmers to include soil conservation as a normal part of their farming practices. It is important to actively involve the farmers to participate at an early stage to achieve sustainability of the conservation activities.

REMEMBER!

Women play a very important role in agricultural production and should therefore be included in training, planning and execution of the activities.

Example of SCAPA strategy for implementation of soil conservation activities

The chart shows different steps in the implementation of soil conservation in a catchment area.

STEP 1. Preparation and organization

I. Practical arrangements
II. Contact local leaders
III. Survey the catchment
IV. First meeting(s)
V. Select Soil Conservation Committee
VI. Train local leaders and SCC

↓

STEP 2. Analysis and Planning

VII. Analyse the information
VIII. Plan the activities

↓

STEP 3. Training of farmers

IX. Training and study tours for farmers

↓

STEP 4. Implementation

X. Organize field activities (promotion days)

↓

STEP 5. Monitoring and Evaluation

XI. Supervise and follow-up

STEP 1. PREPARATION AND ORGANIZATION

I. Practical arrangements

When a need for soil conservation has been identified in an area (which can be done by the farmers and/or the local extension worker), the extension worker should begin by identifying where to start and which farmers to involve initially.

REMEMBER!

- It is advisable to start with a relatively small group of 5–20 farmers who are interested in the activities. The final decision on how to start in a "new" area, of course, depends on the response from the farming community and the resources available.
- If possible, organize and co-ordinate the extension staff working in the area before planning and implementing the activities. Having a team of extension staff who can plan and work together on a wider extension package gives a positive signal to the farming community.

II. Contact local leaders

It is important to seek support and assistance from the leadership to facilitate the activities. The extension worker(s) should identify the area and the target group to be suggested to the local leadership. A meeting with the local leadership from the village and/or the catchment area should thereafter be arranged. During the meeting, the leaders should be informed about the problems facing the area and the activities planned.

III. Survey the catchment

Before initiating any conservation activities, some basic information about the area must be collected and analysed. This is done by making a survey of the area with a group consisting of the extension staff, local leaders and farmers. It is important that the whole group together walks around the area to visually identify and discuss problems in the field.

Below is a list of examples of basic information that should be included in such a survey:

1. Topography of the area. Identify the main direction of run-off, for example, slopes, and if there are outside areas draining into the catchment.
2. Types of vegetation in the area—forest, farm land, grazing land.
3. Farming systems practised. Identify possible solutions to improve production. Analyse and ask about the farming practices to understand the problems.
4. Soil types, fertility and rainfall. Ask the farmers about infiltration capacity, soil depth, intensity and amount of rain.
5. Types and causes of erosion.
6. A short tentative list of possible technologies that could be used to improve the existing farming system, including possible soil conservation techniques.

IV. First meeting(s)

This first meeting is organized by the extension worker together with local leaders to inform the farmers in the catchment area about the intended assistance on soil conservation.

The meeting should be in the form of a discussion where the farmers get the opportunity to ask

REMEMBER!

- Explain which resources are available within your programme and what you can do. It is important that you don't promise something that you can't fulfill.
- Ask the local leaders and some of the farmers to participate in the survey of the catchment. Ask the leaders to assist you in organizing a meeting with the farmers in the catchment area.

questions about soil conservation. They should be able to express their ideas about agricultural production, problems and priorities. The most important aim of soil conservation is to increase or maintain agricultural production on a sustainable basis. Listen to the farmers' priorities and put emphasis on ways and means to increase production using different soil conservation measures.

If there is a positive response from the farmers, explain (with assistance from the leadership) the advantages of having a Soil Conservation Committee (SCC), its responsibilities and how it should work. The SCC can thereafter, if possible, be selected during the meeting.

REMEMBER!

- Use the information collected during the survey.
- Explain firmly your intentions and how you can assist the local community.
- Allocate sufficient time for the farmers to ask questions during the meeting.
- Do not promise something that you can't fulfill.

V. Select Soil Conservation Committee

The Soil Conservation Committee should be responsible for the activities in a given catchment area. The committee should operate on behalf of the village government and is therefore answerable to the village government and extension staff. A strong SCC can assist the extension worker. The extension worker should therefore work closely together with the committee to organize training sessions, meetings and field activities. It is also important that the extension worker practically assist the committee in the initial phase so that members gain confidence to take over the responsibilities.

VI. Train local leaders and SCC members

The main aim with training of local leaders and the SCC members is to create knowledge and understanding of soil erosion and different soil conservation techniques. The leaders and SCC can, with good knowledge and skills, later organize and promote soil conservation activities in their village/catchment area.

The training should be as practical as possible including, for example, training on how to use soil conservation equipment such as the line level. The training could, if possible, also be more detailed compared to farmers training since the committee will be the advisers and organizers of their fellow farmers in the future.

Whether specific training should be conducted for the leadership and the SCC, depends mainly on the number of farmers involved. With a smaller group, the training can include all members in the catchment. The most important points to remember when conducting training, is summarized under *Step 3: Training of farmers.*

REMEMBER!

- The selection of the SCC could be done during the first meeting, or by calling a meeting specifically for the election of the SCC.
- The members of the SCC should be devoted to the task and accepted by the farming community. It is advisable to have at least one representative from the local government as a member of the SCC to strengthen the authority of the committee.
- The size of the committee should preferably not exceed 10 members. Usually a group consisting of a chairman, vice-chairman, secretary and 4–6 committee members is sufficient. At least 2–3 members of the committee should, if possible, be women.
- Soil Conservation equipment like line levels should be provided for the SCC. The committee can thereafter, upon request, lend the equipment to the farmers.

STEP 2. Analysis and planning

VII. Analyse the Information

After receiving relevant information from the first meeting and training of the leaders and SCC members, the extension staff should arrange a meeting to assist the SCC to analyse and plan the forthcoming activities. This meeting should also discuss a schedule for the extension worker's regular visits to the area. It is advisable that the extension worker visit the SCC members and farmers in the area on a weekly basis.

VIII. Plan the activities

A work plan for soil conservation activities in the catchment should be prepared. This should include a suitable timetable for implementation of different conservation activities. See also *Step 4: Implementation*.

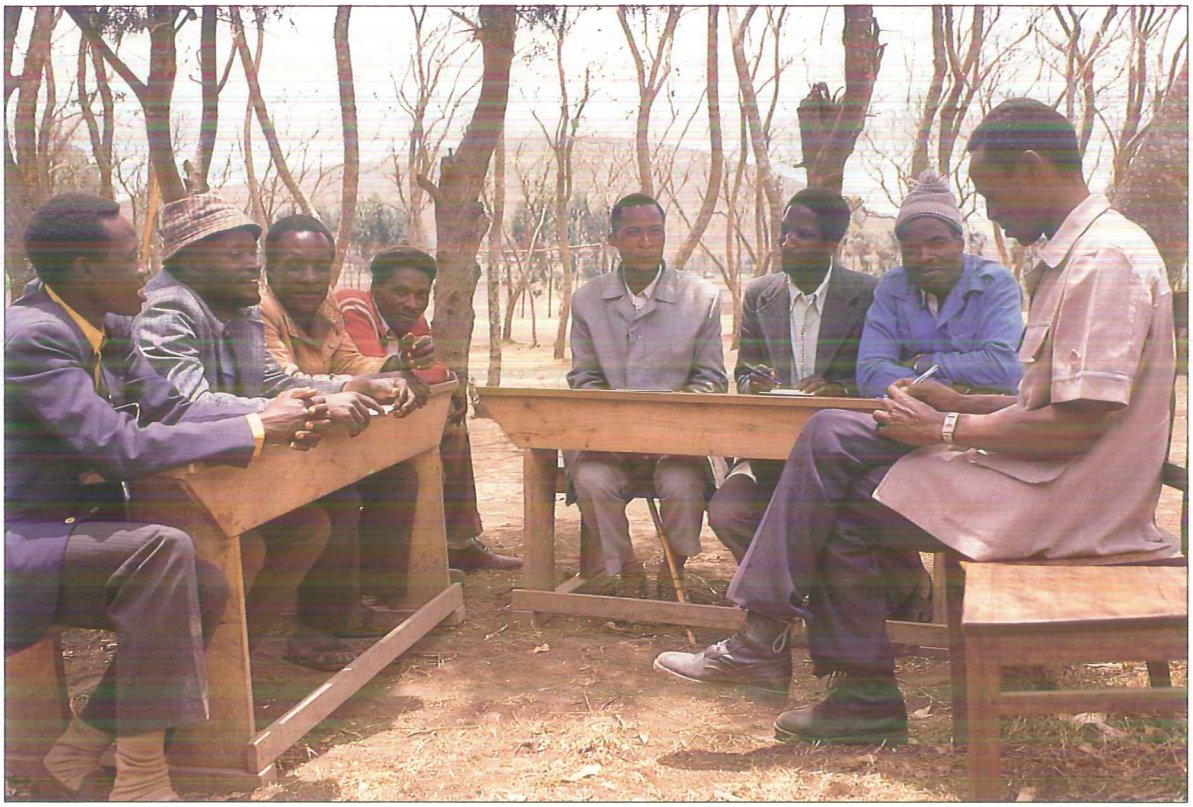


Photo 21. Extension workers and SCC members during a planning meeting. Mukulat Division, Arumeru District. (Photo: Charlotte Thege)

STEP 3. Training of farmers

IX. Training and study tours for farmers

The main aim of this training is to create awareness and basic skills in soil conservation among the farmers. The training could, if possible, be organized with a team of extension workers. This enhances integration and the interdisciplinary approach which provides a uniform message to the farmers.

Where

- Training of farmers should preferably be conducted in a central place in the village/ catchment area.
- The training session should not be longer than 3–4 hours. The number of participants should preferably not exceed 30 people.

When

- Conduct training and study tours at the right time of the season when farmers are not occupied with other activities. The training should be followed by a promotion day where the farmers will receive further practical training.

How

- The training should be as simple and practical as possible. Provide relevant training based on soil conservation techniques and measures suitable for the local environment. Use practical training, for example, use of the line level, construction of a demonstration terrace, planting of fodder grass, trees and shrubs.
- Emphasize agroforestry trees, suitable and accepted in the area, that could be planted and used to increase production.
- Focus the training on soil conservation techniques for increased agricultural production. This could include different farming practices, such as:
  - Increase crop production through soil improvement (nitrogen fixation, soil moisture) and erosion control.
  - Increase fodder production through fodder establishment on contours and introduction of fodder trees.
  - Incorporate agroforestry trees on farm land to increase fuelwood/timber/ fruits/ fodder/crop production

Conducting a study tour

A study tour is one of the most important components of the training of leaders, SCC members and farmers. Study tours provide an opportunity for the farmers to see soil conservation in other areas, practically implemented on farm land. The possibility of discussing and exchanging ideas with fellow farmers who are practising soil conservation is many times the most efficient way to promote soil conservation.

Unfortunately, organizing study tours is sometimes problematic due to lack of transport facilities and/or financial resources. If resources are scarce, the extension worker could try to arrange a study tour for some selected members of the community.

REMEMBER!

- The training should include basic knowledge of good farming practices in agriculture and livestock, as well as agroforestry. Emphasis in either direction will depend on the nature of the problems and the farmers' priorities.
- The extension worker should utilize the training to exchange experiences with the farming community to find a suitable model for soil conservation in the area.
- Participants should have the opportunity to discuss their ideas and solutions.
- Emphasize the participation of women in the training.
- The training should, if possible, include a study tour, giving the farmers an opportunity to see soil conservation practically implemented on farm land. It also gives an opportunity to discuss with fellow farmers who have started soil conservation.

STEP 4. Implementation

X. Organize field activities

Implementation of physical soil conservation structures are carried out in three phases: Lay-out of contours, construction of terraces/contour bunds and planting of grasses/legumes/trees on the constructed terraces.

Conducting a Promotion Day

Promotion days are very important components of SCAPA. The main aim of a promotion day is to organize the farmers to practically participate in the lay-out and implementation of conservation measures in their area. This exercise provides farmers with practical experience and knowledge on soil conservation and provides an opportunity to discuss different practical problems that might occur in the field.

The SCC and the extension worker organize the promotion day together. Many farms can in this way be laid-out at the same time, facilitating co-ordination of structures in the catchment. It is also an efficient way of laying out contours since a lot of work can be done in one day.

The farmers should be trained on the use of the line-level in advance. Farmers work in groups of 3–4 people under the supervision of the extension worker (and SCC members).

SCAPA extension workers from different areas often co-ordinate their activities to assist each other during promotion days. This is very useful especially when handling a large number of farmers and if catchment areas are scattered.

REMEMBER!

- Select the farms to be laid out together with the SCC. The SCC organizes and calls the farmers to be involved.
- Organize so that needed equipment like line levels, spades, *jembes, pangas* and pegs are available.
- Contact extension staff that could be of assistance well in advance.
- Let the SCC and farmers decide the timetable for the promotion day. Do not exhaust people by working beyond the normal working schedule (this risks losing their interest).
- During the promotion day, farmers, the SCC and the extension workers should work together. If several trained workers are available, it is advisable to divide them among the farmers (one extension worker and 3–4 farmers).
- The extension worker responsible for the conservation activities in the area (or an SCC chairman) must be in charge and organize the different groups during the promotion day to avoid misunderstanding and confusion.

REMEMBER!

- Select areas and "host farmers" where the group can benefit in terms of ideas and practices. Do not select areas totally different from where the farmers come from.
- Avoid selecting areas far away. Traveling long distances costs time and money.
- Encourage the host farmer to explain the farming/conservation practices being used.
- Do not bring very large groups to one farmer. This could be impractical for the visitors and create hazards to the host farmer's field. A group should not be bigger than 20–30 participants.

STEP 5. Monitoring and evaluation

XI. Supervise and follow-up

The ultimate goal is that the farmers can take over all conservation activities. It is important that the extension worker puts emphasis on training and organization of the farming community. The extension worker must, in the initial phase, assist and follow-up the conservation activities implemented by the farming community.

REMEMBER!

- Maintenance is very important to achieve sustainability of conservation measures implemented.
- The extension worker and members of the SCC should do continuous follow-up on a weekly basis. Records should be kept for each conserved farm with information on length of terraces, type of planting material and number of trees planted.

Photo 22: SCAPA extension staff conductiong farmer training in Olkolkola village, Arumeru District. (Photo: Charlotte Thege)

8

EQUIPMENT FOR SOIL CONSERVATION

8.1 Soil conservation equipment

There is a variety of survey equipment that can be used in soil conservation. This chapter mainly concentrates on the line level which is commonly used in Tanzania. The line level is a simple tool which is relatively cheap to produce and simple to learn. It also gives accurate measurements.

Another simple and cheap tool is the water ring.

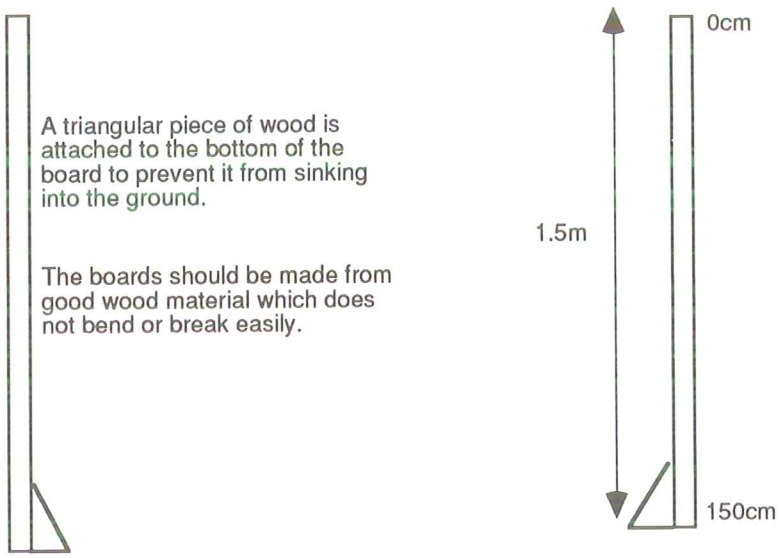
A common piece of equipment used in soil conservation is the "A-frame", which will not be described in this manual since it is found cumbersome to work with and can give inaccurate results.

8.2 The line level

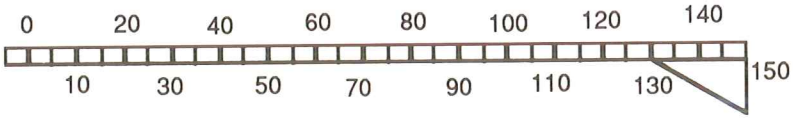
A line level consists of two 1.5m boards, a string with a length of 11m and a spirit level.

Start with the "zero mark" a few centimetres down from the top of each board so as to be able to tie the string to the board. Graduations should be marked with intervals of 5cm, with a larger mark at each 10cm.

Line level boards

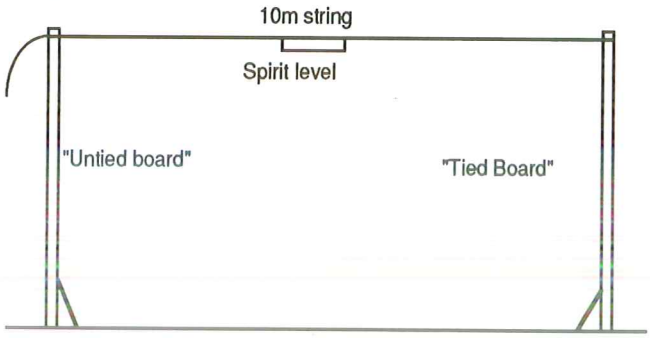


Graduation



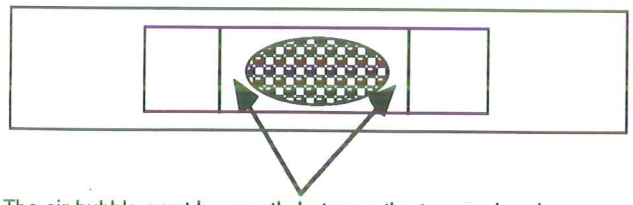
String

Tie a string with a total length of 11 metres to one of the boards. Ten metres is used between the boards, and the extra one metre is for tying the string to the board and for holding the string in the untied end. A knot is made in the middle of the string (5m) where the spirit level is placed, and another knot is made for marking the full string length (10m).



Spirit Level

A spirit level is placed on the middle of the string. The spirit level consists of a small "box" with an air bubble indicating that the string is level. It is important to keep the air bubble exactly between the two marks to avoid measurement errors.



The air-bubble must be exactly between the two marks when measuring.

Before using the line level, the spirit level should be inspected to ensure that it functions properly.

Procedure

1. Set up the line level on the ground and hold the string tight.
2. Hook the spirit level onto the middle of the string. Move the string up or down on one of the boards, until the air bubble in the spirit level becomes exactly in the middle.
3. Remove the spirit level from the string, turn it 180° and replace it on the same place on the string. If the air bubble still remains in the middle position, the spirit level is functioning properly.

8.3. Measuring with the line level

A line level can be used to determine the slope gradient (percentage of a slope), determine the vertical interval (V.I.) and lay out terraces.

STEP 1. Determine the percentage slope

The percentage slope is measured to decide what type of structures and intervals (vertical interval, V.I.) should be used. To measure the percentage slope, three persons are needed: Two persons holding the boards, and one person reading from the spirit level.

Procedure

1. Select a place which is representative of the field and place the line level along the slope. The tied board is placed downslope with the string tied at the zero mark of the board. The untied board is placed upslope.
2. Start by holding the string at the zero mark on the untied board. Keep the string tight and move it slowly down along the graduation marks until the spirit level reads level.
3. Read from the graduation mark on the untied board when the string is level.
4. To make the calculation to determine a percentage slope, all figures must be calculated in metres. The centimetre mark read from the board must therefore be converted into metres: 10cm = 0.1m. (Example: 50cm read from the board = 0.5m.)

REMEMBER!

- The spirit level should always be placed on the middle of the string.
- The untied board is on the same level when laying out level terraces, and uphill from the tied board when determining percentage of slope and vertical interval. The string is tied at the zero mark on the tied board.
- To measure with the line level, three to four persons are needed. Two persons hold the boards, one will read the spirit level and one will mark or peg the terrace.

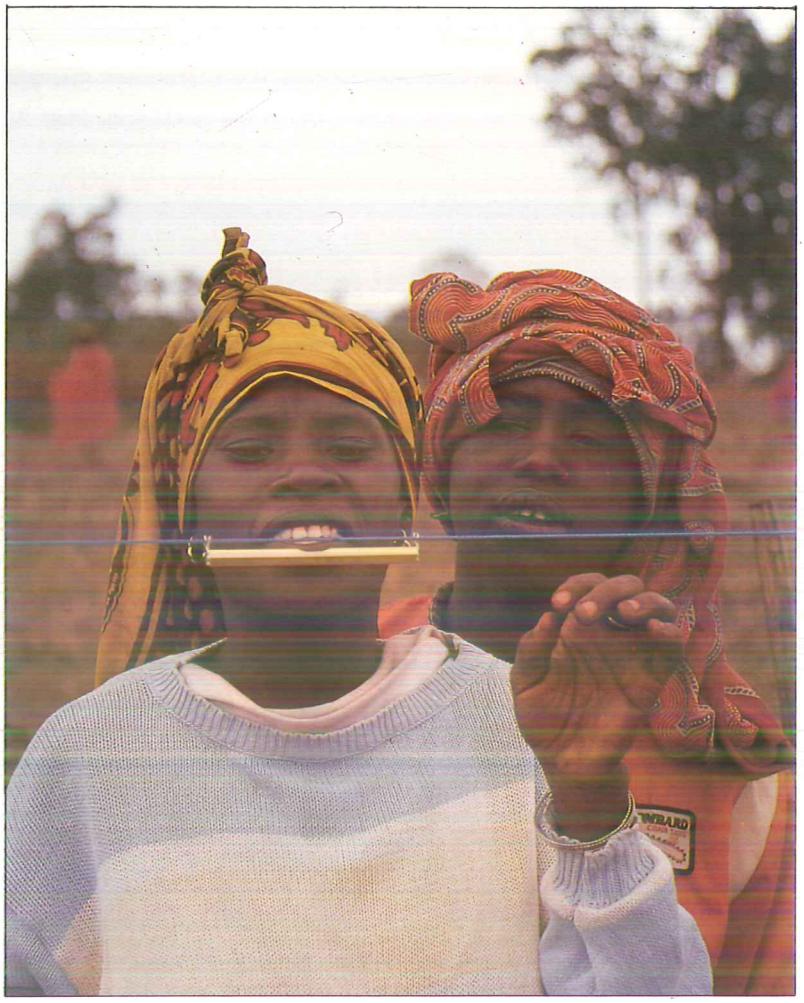


Photo 23. A young farmer checking the spirit level during lay out of terraces in Olkolkola village, Arumeru District. (Photo: Per Assmo)

Gentle slopes up to 15%

For gentle slopes use the whole length of 10m string. The figure read from the untied board with the spirit level in a level position is used in the calculation as shown to determine the percentage slope.

$$\text{Slope \%} = \frac{\text{Difference in height read from the board (Convert centimetre into metre)}}{\text{Length of string (m)}} \times 100$$

Example

$$\text{Slope \%} = \frac{\text{0.9m (90cm) on the board}}{\text{10m string}} \times 100 = 9\%$$

Slopes 16 to 30%

If the slope is steeper than 15%, the string must be shortened to half length (5m). Measure by using the same method as described above, but use 5m string in the calculation.

REMEMBER!

- Always begin measurement by using 10m string. The maximum percentage slope that can be measured with a 10m string is 15%. If the spirit level cannot become level, the slope gradient exceeds 15%.
- The exercise should then be tried with the string shortened to half length, 5m. With a 5m string, percentage slopes up to 30% can be measured. If the slope is steeper then 30%, the string must again be shortened to quarter length, 2.5m.

Example

$$\text{Slope \%} = \frac{\text{0.9m (90cm) on the board}}{\text{5m string}} \times 100 = 18\%$$

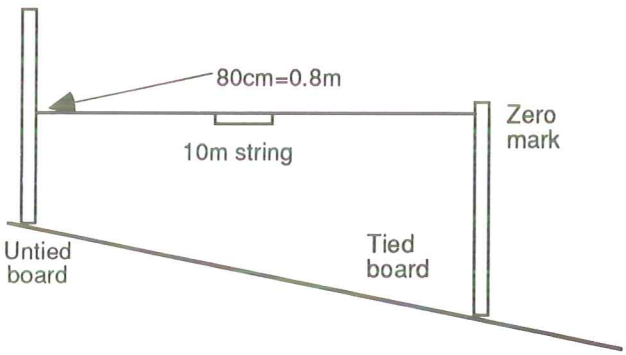
Steep slopes of 31 to 60%

On steep slopes of 31 to 60%, the string must again be shortened to a quarter length (2.5m). Measure by using the same method as previously described, but use 2.5m in the calculation.

$$\text{Slope \%} = \frac{\text{0.9m (90cm) on the board}}{\text{2.5m string}} \times 100 = 36\%$$

Additional examples

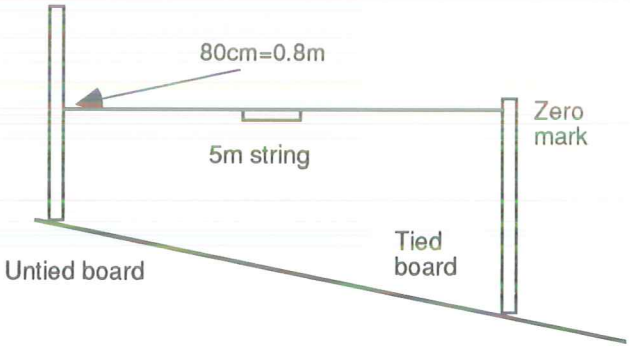
In the example below, 0.8m (80cm) is read from the untied board, using a 10m string. The percentage slope will be as follows:



$$\text{Slope} = \frac{\text{0.8m (80cm) on the board}}{\text{10m string}} \times 100 = 8\%$$

Example

Below is an example from a steeper slope. Eighty centimetres is read from the untied board, using a 5m string. The percentage slope will be as follows:



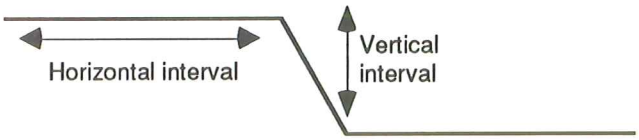
$$\text{Slope} = \frac{\text{0.8m (80cm) on the board}}{\text{5m string}} \times 100 = 16\%$$

Step 2. Determine the vertical interval (V.I.)

A vertical interval (V.I.) is the difference in height from one terrace to the next. A vertical interval of, for example, 2 metres, will determine the height (riser) of a developed bench terrace. A change of the V.I. will also effect the distance between terraces, called the horizontal interval (H.I.). A larger V.I. will increase the distance between terraces and the height of the terrace and vice versa.

V.I. is used to determine the spacing and height of different types of conservation structures. To avoid problems of too high structures, or too long distances between terraces, different V.I.s could

be selected. The V.I. can be calculated from different formulas or determined by using a constant V.I.



Calculations of V.I.

Calculations of V.I. mainly consider the slope gradient factor and the calculations can therefore be misleading. Mistakes in calculations can also cause errors. This manual, therefore, promotes the use of a constant V.I. which can be adjusted according to local conditions.

Constant V.I.

Which constant V.I. (and type of structure) to use depends on the physical conditions, type of farming and cultural practices in each specific area. By reducing the V.I., the distance from one terrace to the next will decrease. The example in Table 3 shows spacing and height of terraces using different V.I.s on a slope with 25% gradient.

Which constant V.I. to be used depends on different factors further explained in Chapter 3.4 on *Spacing of terraces*.

Measuring the V.I.

Measuring of V.I. is normally done in several steps. When the V.I. is measured in several steps, try to divide the measurements into relatively equal steps. A V.I. of, for example 1.8m, could if possible be measured in first 1m, and thereafter the remaining 0.8m.

For a V.I. of 1.5m, the measurement can sometimes be done in one step. This is done by placing the string at the bottom of the untied board. The string is only 10m which restricts the measurement. Spacing between terraces exceeding 10m (which depends on the slope gradient) must therefore be made in several steps also when using a V.I. of 1.5m.

Procedure:

1. Decide which V.I. to use. This example uses a V.I. of 2m.
2. Measure from the upper end of the field, going down the field in the direction of the slope.
3. The string is tied at the "0" mark on the tied board. The tied board is placed downslope and the untied board is placed upslope.

   With a V.I. of 2m used in this example, the measurement must be made in several steps. The string is placed at the 100cm mark on the untied board for the first measurement.
4. The spirit level is placed in the middle of the string. The string is placed at the 100cm mark on the untied board. The person with the tied board moves up or down the slope until the spirit level reads level. The person with the untied board stands still and keeps the string tight.
5. This is the measurement for a 100cm (1m) V.I. Make a temporary mark on the ground at the tied board.
6. Repeat the exercise by placing the untied board at the temporary mark while the person with the tied board moves further down the slope.
7. The second measurement of 100cm = 1m will give a total V.I. of 2m. Place a permanent mark at the tied board.
8. Continue the exercise and mark a V.I. of 2m down the slope until the end of the field is reached.

Horizontal interval (H.I.)

When the percentage slope is determined and the V.I. decided, an H.I. can be calculated. It is not necessary to calculate the H.I. However, such calculation before doing any construction work can be of interest to the farmer for discussion and comparison. With a known V.I. and percentage slope, the H.I. is calculated as follows:

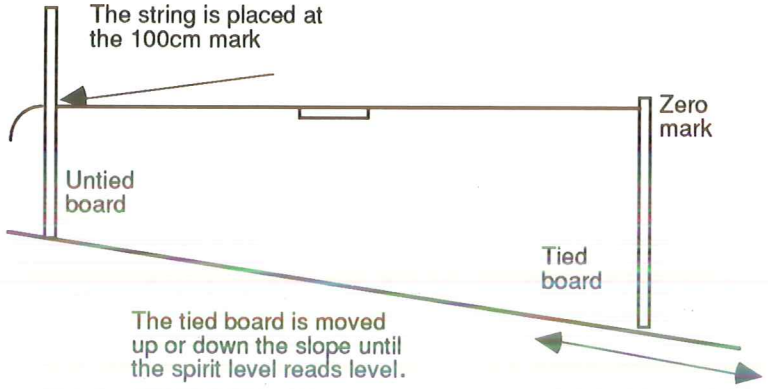
Table 3. Spacing and height of slopes using different vertical intervals

Slope	Height between terraces V.I.	Spacing between terraces H.I.
25%	V.I. of 1.5m	6.0m
25%	V.I. of 2.0m	8.0m

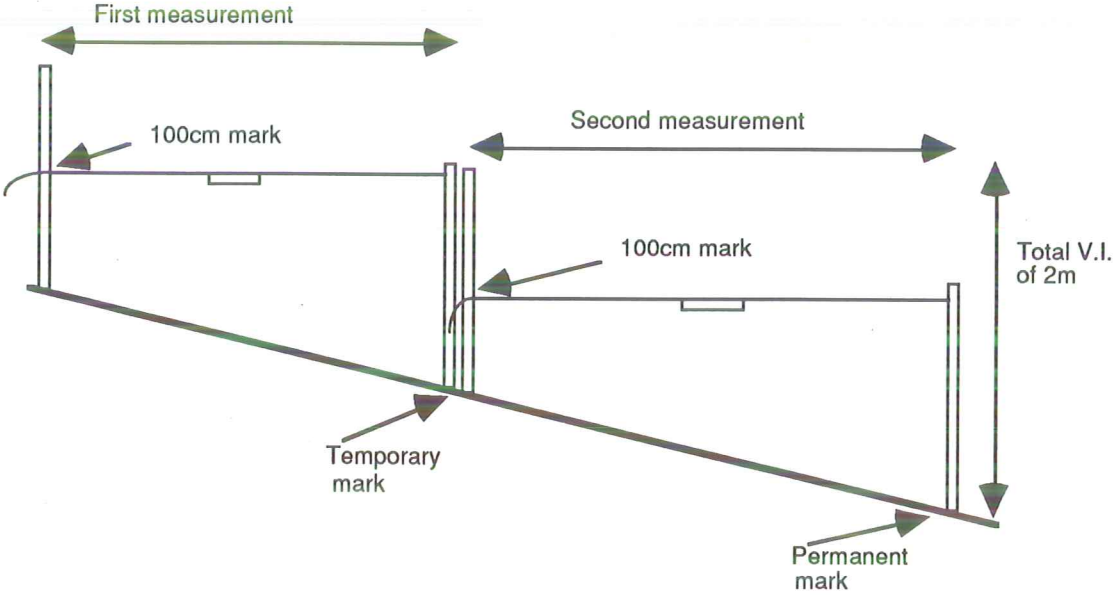
$$H.I. = \frac{V.I. \times 100}{\text{Percentage Slope}} \qquad H.I. = \frac{2m \times 100}{25\%} = 8m$$

Example

First measurement (100cm) for a V.I. of 2m.



Total measurement for a V.I. of 2m



REMEMBER!

- A smaller V.I. should be used for more erodible soils, and the maximum distance between terraces (H.I.) should on such soils not exceed 25m.
- When measuring V.I., the length of the string is not defined and will therefore differ depending on the chosen V.I. and slope gradient.
- If graded terraces are to be constructed, the V.I. should be set out starting from the waterway or discharge point.
- Each measuring point should be well marked because these marks will be the starting point for lay-out of each contour. Remove the temporary marks to avoid mistakes.

Step 3. Lay-out of terraces

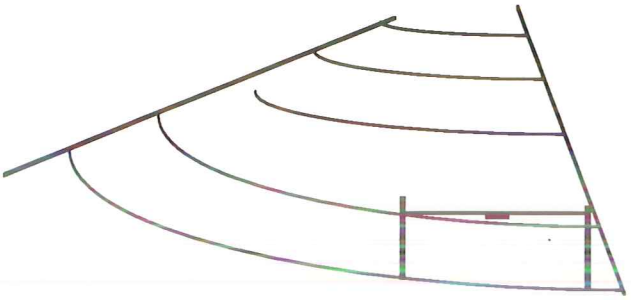
The lay-out of terraces starts from each mark or peg that was put during the measurement of terrace spacing. Start lay out from the top of the field. Three or four persons are needed to lay out terraces. Two people holding the boards, one reading the spirit level and keeping record of terraces measured, and possibly one pegging/ marking the terrace.

Lay-out of level terraces

For the lay-out of level terraces, the length of the string is not defined. To avoid confusion, however, it is advisable to use the full length of the string (10m). On irregular slopes with depressions the string can be shortened to half length (5m). Level terraces are further described in Chapter 3.4 on *Terrace gradients.*

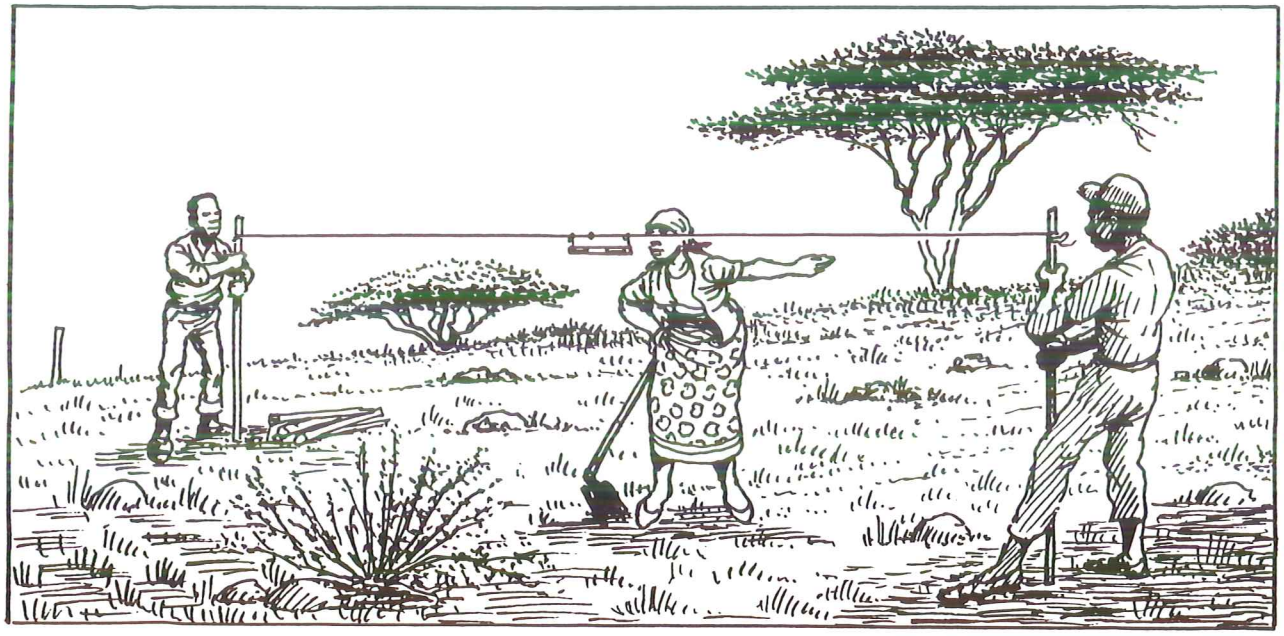
Procedure:

1. Put the string at the zero mark on both boards.
2. Start from the top of the field, at the first V.I. mark, and lay the contour across the slope.
3. The person with the tied board starts from the first V.I. mark. The person by the spirit level directs the person holding the untied board to move up or down hill, while keeping the string tight, until the spirit level reads level.
4. Place a peg into the ground by the untied board. Repeat the process with the tied board being moved to the new peg.
5. The contour could be more permanently marked by ploughing or digging so as not to disappear in case the pegs are moved or lost.



Lay-out of graded terraces and cut-off drains

The procedure to lay out graded terraces is basically the same as for level terraces. To measure a gradient with the line level, the string is placed down on the untied board. Which gradient to be used depends on different factors described in Chapter 3.4 on *Terrace gradients.*



Three persons are needed to lay out terraces using the spirit level.

1. Use 10m string. Depending on the gradient that has been decided, place the string on the untied board as follows:

•String at 5cm on untied board = 0.5%
•String at 2.5cm on untied board = 0.25%

If half length (5m) string is used, the gradient is multiplied by 2 as follows:

• String at 5cm on untied board = 0.5%x 2 =1%
• String at 2.5cm on untied board = 0.25%x 2 =0.5%

2. Laying out graded terraces must start from the outlet point so that run-off from the channels drain into the intended drainage area. The tied board must start at the V.I. point/outlet point with the untied board moved up or down the slope until the spirit level reads level.

REMEMBER!
It is important that the terraces are laid in smooth curves across the slope. Avoid sharp corners and depressions where water can break through and develop rills or gullies. When laying out terraces, it is important to visually check each terrace line before construction, and smoothening out the terrace marks/pegs if necessary.

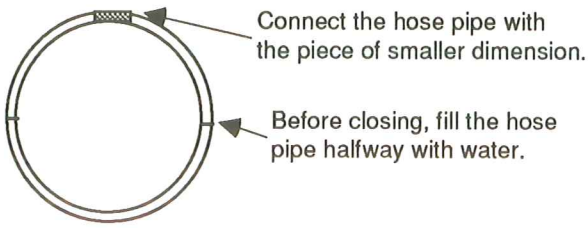
8.4 The water ring

With a water ring it is possible to lay out level terraces and measure a constant V.I. The water ring is a simple tool to use, although it can be difficult to measure with good accuracy. It is therefore advisable to use a line level in more problematic areas. Factors to be considered are generally the same for using a water ring as for using a line level.

Construction of a water ring

The following materials are needed to construct a water ring:

- One piece of transparent hose pipe, diameter 10-15mm and length 70–80cm.
- A short piece of hose pipe, approximately 4-5cm, that fits inside the longer hose pipe This small piece is used to connect the water ring and must therefore fit exactly. The water ring is filled halfway with water and functions thereafter as a levelling instrument.



Measuring with a water ring

Comparing this instrument to a line level, the water ring will function as the spirit level. The eye-height of a man will be equal to the line level board.

1. To make measurements, one water ring and two persons are needed. Start by measuring the eye-height (from feet up to the eyes) on both people.

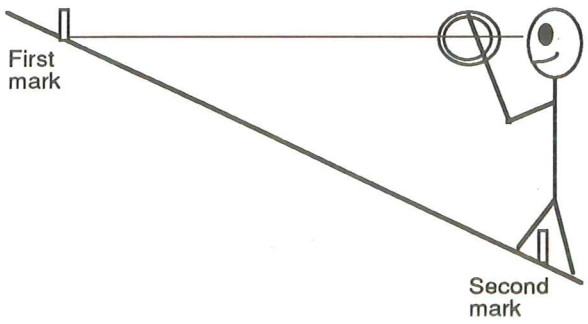
   It is easier if the two persons are of the same height. If not, indicate a mark on the second person, equal to the eye-height of the person who will use the water ring. It is also possible to use a stick and mark the stick at the point equal to the eye-height of the person with the water ring.

   Always use the eye-height of the person measuring with the water ring.
2. Hold the ring in front of one eye and look through the ring towards the next person's eyes (or indicated point). When one person can see into the next person's eye (indicated point), through the two water surfaces in the ring, the imagined line between is level.

Measuring a constant V.I.

A constant V.I. (equivalent to the person's eye-height) can be measured with a water ring.

Start by placing a peg at the top of the field. The person with the water ring thereafter moves down hill until it is possible to see through both water surfaces in the water ring and onto the first peg. The V.I. will in this case be the same as the person's eye-height.



A second peg is placed right beneath the person measuring. This will be the next V.I. point. The exercise is thereafter repeated down the field.

Laying out level contours

1. The person with the water ring moves across the slope, approximately 10m while the other person stands at the fixed peg.
2. The person with the water ring looks through the ring and moves up or down the slope until it is possible to see through both water surfaces in the ring and into the next person's eyes.
3. Make a mark right beneath the person with the water ring. Repeat the exercise across the slope.

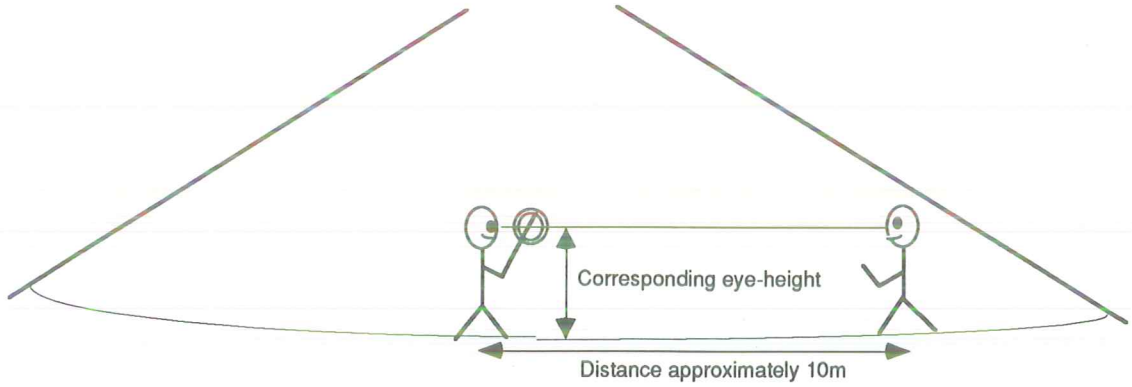


Photo 24. Measuring with a water ring in the forest areas of Olmotonyi, Arumeru District. (Photo: Charlotte Thege)

APPENDIX 1

Some useful trees and shrubs in Tanzania

This appendix presents some selected tree species which are commonly used in Tanzania. This information is extracted from the book *Useful Trees and Shrubs for Tanzania* published by the Regional Soil Conservation unit RSCU/SIDA in Nairobi, 1994.

Acacia albida (Faidherbia albida) *Mimosoideae*

Indigenous

Common names: Apple ring acacia, winter thorn. **Swahili:** *mkababu, mgunga.*

Ecology: Within Africa widespread in semi-arid areas. Prefers semi-arid and riverine zones in Tanzania, altitudes ranging from sea level to 1800m. It grows well in areas with a high water table and alluvial, loamy or sandy soils which drain well.

Uses: Firewood, charcoal, timber (construction), posts, utensils, flavouring (pod), medicine (bark), fodder, (pods and leaves), shade, nitrogen fixation, soil conservation and improvement.

Description: One of the tallest of the Acacias, sometimes to 30m with high rounded spreading crown. Branchlets zigzag, shiny grey. **bark:** dull grey, fissured and scaling. **thorns:** in pairs, straight to 2cm often pointing downwards. **leaves:** compound, 3–8 pairs of pinnae each with 6–23 (usually 9–16) pairs of grey-green leaflets, up to 1cm, rounded and overlapping. **flowers:** in slender spikes to 14cm, cream-white, attracting bees. **fruits:** distinctive twisted pods, smooth bright orange, to 25cm long and quite thick, edge thickened, containing 10–20 seeds which ripen at the end of the dry season. Seeds are set free when the pods rot on the ground.

Propagation: Seedlings, direct sowing.

Seed Info.: No. of seeds per kg: about 9,000. **treatment:** nick the seed or immerse in hot water, allow to cool and soak for 24 hours. **storage:** seed can be stored for many years if dried properly and kept in a dry cool place free from insects.

Management: Slow initial growth, later fairly fast growing on good sites, and even in poor sites provided the water table is high.

Remarks: The tree is widely used in dryland agroforestry. It is deep rooted and does not compete with food crops.

Albizia gummifera
Mimosoideae

Indigenous

Common names: Peacock flower. **Swahili:** *mkenge.*

Ecology: Mainly found in East Africa, but also in Ethiopia, Zaire, Madagascar and West Africa. In Tanzania it is found from the coastal hills to Kilimanjaro and Kagera, 600-2,350m.

Uses: Firewood, timber (general purposes), utensils (mortars, water troughs), beehives, medicine (pods, roots, bark), fodder (leaves), bee forage, soil conservation, nitrogen fixation, ornamental, shade.

Description: A large deciduous tree, branches ascending to a flat top, about 15m high, trunk up to 75cm in diameter. **bark:** grey and smooth. **leaves:** shiny, dark green leaflets, almost rectangular, midrib diagonal, one outer corner rounded. **flowers:** white-pink clusters, long stamens hang out. **fruits:** very many pods in bundles, shiny brown, flat with raised edges, 20cm long, 3cm wide, often shorter, 8–14 flat, brown seeds.

Propagation: Seedlings, direct sowing, wildings.

Seed Info.: No. of seeds per kg: 10,000–15,000. Good seed germinates within 3–10 days at optimum rates of 70%–80%. **treatment:** fresh seed requires no pre-treatment. Soak previously stored seeds in warm water and leave to cool to room temperature. The seed coat can also be nicked at the cotyledon end to hasten germination. **storage:** seed can be stored for at least a year if kept dry and insect free.

Management: Fast-growing, lopping, coppicing while young.

Remarks: Seed should be collected while still on the tree to minimize insect damage.

Annona senegalensis (A. chrysophylla)
Annonaceae

Indigenous

Common names: Wild custard apple, wild soursop. **Swahili:** *mchekwa, mtopetope, mtomoko mwitu.*

Ecology: A wild fruit tree found all over Africa in semi-arid to sub-humid regions. In Tanzania, it grows in wet lowland savannah at the coast, in the Usambaras and in Lake Victoria basin. It grows well in a variety of soils, mostly as an understorey shrub, 0–2,000m.

Uses: Fruit, medicine (root, gum, fruit), fodder (leaves), dye (bark).

Description: A shrubby deciduous tree, usually 2–6m. **bark:** grey and smooth, thick and folded when old, young stems hairy and orange. **leaves:** oval and rounded, blue-green to 18cm long, hairy below, a peculiar smell when crushed. **flowers** 1–3 small flowers hang down below twigs, yellow-green petals and sepals in threes. **fruits:** rounded 2–7cm smooth with divisions. Green when unripe, turning orange-yellow when ripe and smelling like pineapple, the sweet pulp surrounding many seeds is edible.

Propagation: Seedlings and wildings.

Seed Info.: No. of seeds per kg: 2,500-3,000. Germination is good but sporadic. **treatment:** no treatment required. **storage:** seeds susceptible to insect damage and lose viability within 6 months.

Management: Very susceptible to fire and weeds. Needs shade from other trees.

Azadirachta indica
Meliaceae

N.E. India, Burma

Common names: Neem tree, Margosa tree. **Swahili**: *mwarubaini, mkilifi*

Ecology: A well-known tree in its natural range (India) and today widely planted in Africa. Pan-tropical in semi-arid and arid regions, withstanding drought. In Tanzania it has been recommended for very dry areas and poor soils, 0–1,500m. Roots grow deep and spread over a wide area, does not stand waterlogging.

Uses: Fodder (leaves, oil-seed cake), bee forage, soil conservation, ornamental, shade, windbreak, insecticide (azadirachtin in leaves), oil (seeds), soap (seed oil).

Description: A fast-growing, medium-sized tree which may reach 20m, with a dense, leafy, oval-shaped canopy, evergreen. **bark:** pale grey-brown, grooved and rough at maturity. **leaves:** glossy green, crowded at the ends of branches, compound to 40cm long, each leaflet curved and long pointed, the edge roughly saw toothed, leaf blades unequal, a small leaflet at the leaf tip. **flowers:** small, fragrant, creamy white, hanging in long graceful sprays. **fruits:** oval yellow berries when ripe, 2cm long, thin skinned with oily pulp around 1–2 seeds.

Propagation: Seedlings, wildings, stumps, direct sowing.

Seed Info.: No. of seeds per kg: about 5,000. **treatment:** not necessary, sow seeds immediately after collection and extraction. Germination can be improved by nicking the seed coat at the round end. **storage:** seed can be stored only for a very short period under field conditions. Use fresh seed for best results.

Management: Fast-growing, lopping, pollarding.

Remarks: The wood is tough and resistant to decay and termites. Highly valued almost throughout Tanzania for its medicinal uses (reputed to cure 40 different diseases). It spreads easily and may become a weed in some areas.

Bauhinia petersiana
Caesalpinioideae

Indigenous

Common names: White bauhinia. **Swahili:** *mgobwali.*

Ecology: Commonly found at low and medium altitudes in most woodland types and on anthills, 150–1,800m. Also found in Zaire, Zambia, Mozambique.

Uses: Food (seeds), medicine (roots, leaves), fodder (leaves, pods), shade, ornamental, tannin (roots).

Description: An evergreen or semi-deciduous shrub or tree to 8m or with a spreading rounded crown, branchlets with brown hairs. **bark:** pale to dark brown, smooth, powdery when young, flaking in vertical strips when old. **leaves:** alternate simple, blue-green, divided into two lobes, lobes 3–9cm across, feel hairy below. **flowers:** fragrant, white, stamens pink, petals wavy, bent back. **fruits:** a brown pod, smooth, to 18cm long, 6–8cm wide. Splitting explosively when mature, 5–8 brown-purple seeds, oily and shiny. Dry spiral pods remain on tree.

Propagation: Seedlings, direct sowing.

Seed Info.: No. of seeds per kg: 1,500. **treatment:** soak in cold water for 12 hours. **storage:** can be stored in cold conditions.

Management: Pruning, coppicing, pollarding.

Remarks: People eat the seeds during famine. Other common Bauhinia shrubs that have been planted in Tanzania, especially in the lowlands are *B. galpinii (B. punctata)* and *Bauhinia acuminata.*

Bauhinia variegata
Caesalpinioideae

India, Tropical Asia, China

Common names: Bauhinia, camels' foot, orchid tree.

Ecology: A tree grown throughout the tropics, and in Tanzania grown up to 1,500m. Commonly planted in gardens and avenues in most towns throughout the country.

Uses: Firewood, tools, food (shoots as vegetables) fodder, shade, ornamental, soil conservation, soil improvement, tannin.

Description: An attractive small, semi-deciduous tree, usually to 6m but sometimes much taller. **bark:** grey and smooth, furrowed and flaking with age. **leaves:** alternate, dull blue-green, the two lobes 10–15cm across (camel-foot shaped), veins radiating from the leaf base. **flowers:** pink-white in short sprays, each flower with five petals marked with rose or yellow-green, one petal different in shape and colour (orchid like), five arched stamens. **fruits:** flat brown pods to 20cm long, twisted open to release round flat seeds 1cm across.

Propagation: Seedlings, direct sowing.

Seed Info.: No. of seeds per kg: 4,200–5,700. Germination rate is about 70%, completed after 3 weeks. **treatment:** not necessary for fresh seeds. Soak stored seeds in cold water for 24 hours. **storage:** If sun dried and stored at room temperature seed can retain viability for some months. Best germination from fresh seeds.

Management: Coppicing, lopping, pollarding.

Remarks: In India and Nepal flowers are used for vegetables and pickles. The heavy hard wood makes good tools.

Bridelia micrantha
Euphorbiaceae

Indigenous

Common names: Bridelia. **Swahili:** *mkarati, mtutu.*

Ecology: A tree of the high potential areas in East and Southern Africa, in forests by rivers, forest edges or open woodland, 0–2,200m. It does well in a wide variety of climates.

Uses: Firewood, charcoal, timber, poles (granaries), tool handles, fruit, medicine (bark and roots), fodder (leaves), mulch, shade.

Description: A medium-sized leafy evergreen tree with dense spreading crown, to 13m. **bark:** grey-brown flaking with age, young stems zig-zag, dotted with paler breathing pores. **leaves:** appear compound but actually alternate along branches, dark shiny green above, to 12cm long, veins parallel extending along margin, leaf stalks slightly hairy. **flowers:** small and yellowish, bunched in leaf axils, male and female flowers on different trees. **fruits:** soft purple-black, oval up to 8mm, sweet and edible when ripe.

Propagation: Seedlings, wildings.

Seed Info.: Prolific seeder. No. of seeds per kg: 19,000–19,500. Germination is very good and uniform, up to 90–100 % after 20–25 days. **treatment:** not necessary, use only fresh seed. **storage:** short viability (oil seeds), do not store.

Management: Fast-growing in good sites, pollarding, coppicing.

Remarks: The species is becoming scarce due to over-exploitation. Not planted near homesteads as it attracts caterpillars and birds. Wood resistant to termites. Commonly intercropped and managed by small-scale farmers.

Cajanus cajan
Papilionoideae

South East Asia

Common names: Pigeon pea. **Swahili:** *mbaazi.*

Ecology: The genus is now recognized to have 32 species. It reached West Africa and the West Indies early as a food crop. It is a hardy, drought resistant and widely adaptable crop growing in a variety of soils, provided they are not saline or waterlogged, 0–3,000m.

Uses: **Firewood, food** (fruit and seeds), fodder (foliage), bee forage, mulch, green manure, nitrogen-fixation, soil conservation, soil improvement.

Description: A slender shrub 2–5m, annual or perennial, becoming woody with age. **bark:** brown, thick stems ribbed and densely hairy. **leaves:** compound with three leaflets hairy white below, 2–8cm long. **flowers:** usually yellow, in terminal groups, the large petal has red lines outside, buds yellow sticky. **fruits:** curved pods, about 5cm long, hairy with about 4–5 green-grey seeds.

Propagation: Direct sowing.

Seed Info.: Seeds highly susceptible to insect attack. Germination rate very high. **treatment:** soak in cold water for one day. **storage:** stores well if kept dry, cool and insect free.

Management: Fast-growing, weeding is necessary.

Remarks: A useful, high yielding crop for dry areas. Improved perennial "tree types" are available. It is, however, susceptible to pests and diseases. Root extracts are used for stomach ache and as an aphrodisiac.

Calliandra calothyrsus
Mimosoideae

Central America

Common names: Calliandra.

Ecology: Brought very recently to Tanzania, the tree does well in a variety of soils including acidic ones, 1,500–2,000m and it can do well at higher altitudes than *Leucaena*. It can tolerate several months of drought but does best with high rainfall. It does not tolerate waterlogging.

Uses: Firewood, poles, fodder (leaves, twigs), bee forage, shade, ornamental, mulch, nitrogen fixation, soil conservation, soil improvement, windbreak.

Description: A large multi-stemmed shrub, 4–6m, branches spreading, maximum stem diameter in good conditions 20cm. The canopy can be quite dense. **bark:** grey-brown, smooth. **leaves:** compound, dark green, folding at night, shed in a long dry season. **flowers:** showy red "brushes" of many long shiny stamens, very many on the stalk. **fruits:** a pod about 10cm long which breaks open, each half curling back to set free up to 15 seeds.

Propagation: Seedlings.

Seed Info.: No. of seeds per kg: about 19,000. **treatment:** immerse in hot water, allow to cool and soak for 12 hours, or soak in cold water for 24 hours. **storage:** seed stores well for 1–2 years.

Management: Very fast-growing on good sites, lopping, coppicing.

Remarks: Although the tree coppices well, the vigour of a stand declines with age and it only lasts for about 12 years. Beetles attack flowers and hence reduce seed production. A high tannin content reduces its palatability as fodder but the foliage contains 22% protein. The wood is dense and burns well but is often attacked by ants. Woody

stems can be harvested from 3–5cm diameter. Useful for reforestation as it can be planted beneath stands of taller trees.

Carica papaya
Caricaceae

Tropical America

Common names: Pawpaw, papaya. **Swahili:** *mpapai.*

Ecology: A short-lived tree. In Tanzania, it has been widely introduced into villages and towns. Along the coast and in Zanzibar pawpaw is well established and naturalized up to 1,500m but performs better below 1,400. Suitable soils are well drained, fertile, slightly acid (pH 6–6.5). It has a shallow root system.

Uses: Food (fruit), drink (fruit), medicine (roots), pickles, jam (fruit) meat tenderizing (leaves, fruit).

Description: A tree-like herb 2–10m, the trunk about 20cm across, narrowing to a crown of leaves. Stem suckers often develop but branching only when the terminal bud is damaged. The trunk contains soft fibrous wood. **bark:** grey, smooth, well marked with leaf scars. **leaves:** up to 60cm across, deeply palmately lobed, the hollow stalks to 60cm long. **flowers:** male trees abundant flowers on dropping stalks, cream-yellow, about 2cm long, tubular, and fragrant. Female trees larger, few flowers beside leaves. **fruits:** In Tanzania about three months to mature, oblong to spherical, 7-50cm long and 15cm across, thin skin, green to orange.

Propagation: Seedlings, direct sowing.

Seed Info.: Collected from ripe fruit. No. of seeds per kg: 20,000. **treatment:** air dried. **storage:** store in cool and dry condition. Viability up to 3 years.

Management: Direct sowing is better than seedlings for fruit production; grows easily from seed. Sow 5–30 seeds together and germination takes 1–4 weeks. Weeding is essential as pawpaw is sensitive to root damage. In plantations space plants 2–4m apart and leave one male tree in an orchard for every 25–100 female trees.

Remarks: Pawpaw is recommended for all parts of Tanzania below 1,500m. Large-scale planting is possible in the coastal zones with higher rainfall. Meat can be tenderized by wrapping it in pawpaw leaves. Trees do well for 3–4 years; the yield falls, so plant every 4 years on a fresh site. Pawpaw is attacked by several weevils, bugs.

Cassia siamea (Senna siamea)
Caesalpinioideae

S.E. Asia

Common names: Iron wood, yellow cassia. **Swahili:** *mjohoro.*

Ecology: A small tree cultivated all over the tropics from sub-humid to semi-arid and even arid zones, 0-1,600m. It prefers a high watertable but will tolerate extended drought and a variety of soils. In Tanzania *Cassia siamea* is widely grown in drier areas, below 1,000m. The most suitable soils are deep, fairly fertile, well drained and neutral or alkaline in reaction.

Uses: Firewood, charcoal, poles, timber (furniture), medicine, fodder (leaves), bee forage, ornamental, soil conservation, windbreak.

Description: An evergreen tree to 20m, often shrub-like. **bark:** smooth, pale grey-brown. **leaves:** compound, stalk to 30cm, grooved, leaflets oblong, round at base and tip which may be notched, dark, shiny, green above. **flowers:** pale yellow in dense heads, each flower about 3cm across. **pods:** in dense clusters, flat yellow-brown

and smooth, slightly curved, indented across, about 20 seeds within.

Propagation: Direct sowing, seedlings, wildings.

Seed Info.: A prolific seeder. No. of seeds per kg: 39,000 **treatment:** fresh seeds require no pre-treatment, nick or soak stored seeds up to 48 hours in cold water or pour on boiling water and leave to soak for 24 hours. **storage:** seed can be stored up to one year but germination rate drops with time.

Management: Fast-growing, lopping, coppicing.

Remarks: Most widely planted fuel tree in the lowlands of Tanzania, with dense wood, but gives a smoky fire. The species is not browsed so it is easily established. Should not be mixed with crops as it competes. Susceptible to mildew attacks on the leaves. In Tanzania, *Cassia siamea* is recommended as a woodlot tree where conditions are favourable. (*Senna siamea* is now the correct name.)

Cassia spectabilis (Senna spectabilis)
Caesalpinioideae

Tropical America

Common names: Calceolaria Cassia. **Swahili**: *mhoba.*

Ecology: Native to central and northern South America. It has been introduced in Africa as an ornamental tree. *Cassia spectabilis* is tolerant to cool conditions (15–25°C) and in Tanzania therefore suitable for elevations up to 2,000m. Will grow well with a mean annual rainfall of 800–1,000mm in deep, moist sandy or loamy soils.

Uses: Firewood, charcoal, tool handles, bee forage, shade, ornamental, mulch.

Description: A small rounded deciduous tree generally less than 10m tall, even at maturity. The bole is short and tends to fork near the ground. Bare for several months. **bark:** smooth, grey with horizontal markings. **leaves:** compound to 40cm, with many pointed leaflets, often softly hairy below. **flowers:** golden yellow in erect pyramid clusters to 60cm high, all over the tree. **fruits:** long cylindrical or flattened pods, turning from green to black, the seeds in separate compartments.

Propagation: Direct sowing, seedlings.

Seed Info.: No. of seeds per kg: about 39,000. Seeds profusely. **treatment:** immerse in hot water, allow to cool and soak for 24 hours. **storage:** under cool dry conditions the seed can be stored for up to two years.

Management: Fast-growing in good sites, coppicing.

Remarks: Wood is resistant to termites. Easy to raise and less susceptible to pests and diseases than *Cassia siamea*.

Casuarina cunninghamiana
Casuarinaceae

Australia, Pacific Islands

Common names: Greek oak, river oak. beefwood. **Swahili**: *mvinje.*

Ecology: In East Africa successful plantations have been established in highland areas such as Ethiopia, and in Tanzania it is grown in several mountain areas. It prefers well-drained soils but grows satisfactorily in a variety of soils. Altitude range 1,500-2,000m and rainfall 600-1,500mm.

Uses: Firewood, charcoal, poles, posts, timber, shingles, tool handles, yokes, fodder (young branches), shade, ornamental, mulch, nitrogen fixation, soil conservation, soil improvement, windbreak.

Description: An evergreen tree up to 20m, pyramidal in shape when young, a shady crown. The bole to 75cm in diameter and lowest branches 2m above the ground. **bark:** grey and smooth becoming grey-black, much cracked with age. **leaves:**

thin branchlets have taken over the leaf function in this family; leaves remain as minute scales at each joint. Grey-green branchlets 9–20cm long in upturned bunches. **flowers:** male flowers are seen as yellow pollen-bearing tips to branchlets, female flowers are tiny heads with hairy red stigmas, on woody branches. **fruits:** in dense clusters, prickly brown capsules, 1cm long. When ripe they release hundreds of tiny winged seeds, paled in colour.

Propagation: Seedlings, root suckers.

Seed Info.: No. of seeds per kg: 1,400,000-1,600,000. Tree seeds prolifically. Good germination rate (55%-90%). **treatment**: not necessary. **storage**: seed can be stored for up to two years in a dry, cool place.

Management: Fairly fast-growing from seedlings. Root suckers from felled and standing trees can be developed and managed.

Remarks: Seedlings susceptible to termites. Aggressive growth and may thus compete with crops. In Tanzania it is recommended for planting in the highlands as a source of timber and soil improvement. The wood is very hard and difficult to saw and season. The special root association with a fungus enables Casuarina to fix nitrogen in the soil.

Cordia africana (C. abyssinica)
Boraginaceae

Indigenous

Common names: East African cordia. **Swahili:** *mringamringa.*

Ecology: A large forest tree of moist warm areas, woodland and bush. It is common in pastureland 1,200-2,000m, particularly in Arusha and Kilimanjaro regions, but also grows elsewhere in scattered areas in Tanzania. Tolerates a wide variety of soils.

Uses: Firewood, timber (furniture), roof shingles, beehives, utensils (mortars, boxes), medicine (bark), fodder (leaves in dry season), bee forage, shade (coffee), mulch, soil conservation, boundary demarcation.

Description: A much branched deciduous tree with rounded crown and often crooked trunk, 4-15m. **bark:** pale brown, finely grooved but rough with age. **leaves:** large, oval to 16cm, base rounded, veins prominent below, young shoots, leaf stalks, underside of leaves covered with soft brown hairs. **flowers:** showy, funnel shaped, thin white petals, sweetly-scented and attractive to bees. **fruits:** yellowish, 1cm in hairy cups. Flesh sticky, each fruit containing 4-6 seeds.

Propagation: Wildings, seedlings.

Seed Info.: No. of seeds (strictly fruits) per kg: 2,500-4,500. Germination rate is 50-80%. Slow germination (40-60 days). Produces seed from August to September. **treatment:** No treatment or soak in cold water for 6 hours. **storage:** properly dried seed stores well up to 1 year.

Management: Moderate to slow-growing, pollarding, lopping, coppicing. Requires over 6 months in a nursery before planting out.

Remarks: The heartwood is hard and takes a good polish so the timber is prized for furniture, but it can be twisted and difficult to saw. It is often found in cropland where it is managed to reduce shade. Provides very good mulch.

Croton macrostachyus
Euphorbiaceae

Indigenous

Common names: Broad leaved croton.

Ecology: A medium-sized tree of eastern Africa, widespread in areas with high rainfall in forest margins and along roadsides. In Tanzania very

common around Kilimanjaro, Meru and in Iringa, Mbeya and Rukwa, 1,100-2,500m.

Uses: Firewood, timber, poles, tool handles, medicine (sap, leaves, roots, bark), fodder, bee forage, mulch, green leaf manure, soil conservation, ceremonies.

Description: A deciduous tree, crown rounded and open with large spreading branches to 25m. **bark:** pale grey, fairly smooth. **leaves:** large, soft and heart-shaped, to 15cm long, on long stems crowded at the end of branchlets, veins prominent with 2 stalked glands just visible at the leaf base. **flowers:** cream-yellow, sweetly scented in erect spikes to 25cm. The flower spike turns down as fruits mature. **fruits:** pea-sized capsules on drooping spikes, to 30cm, mature capsules split open with a sharp noise to release shiny grey seeds with a soft, cream aril.

Propagation: Seedlings, wildings.

Seed Info.: No. of seeds per kg: 16,000-27,000. Seed usually damaged by insects while on the tree. Germination is good, 40-70% in 30-60 days. **treatment:** not necessary, inside of viable seeds must be white-cream coloured. Collect seed from mature grey fruit. Sun dry to release seed. **storage:** seed will store for some months if kept cool, dry and free from insects.

Management: Fairly fast-growing on good sites, lopping, pollarding and coppicing.

Remarks: Seed and resin are poisonous. When cut it has a rather unpleasant spicy odour. The soft light wood is very perishable and does not make good timber.

Croton megalocarpus
Euphorbiaceae

Indigenous

Common names: Croton.

Ecology: A dominant upper storey tree in some forested areas of East Africa, widespread in the mountain areas of Kilimanjaro, Meru, Ngorongoro and Usambara. It can be found in a range of semi-humid habitats, 1,200-2,400m, but has been planted at lower altitudes.

Uses: Firewood, charcoal, timber, poles, medicine (bark), bee forage, shade, ornamental, mulch, live fence, boundary marker.

Description: A spreading tree to 35m with distinctive layering of branches, the crown rather flat and giving light shade. **bark:** dark grey, rough, cracking. **leaves:** variable, long oval and pointed to 12cm but often much smaller, stalked. The dull green upper surface contrasts with the pale, silvery underside. **flowers:** very short-lived but conspicuous, the buds opening after heavy rains into pale yellow, hanging spikes to 25cm, with only a few female flowers at the base. **fruits:** very many grey woody capsules, about 2.5cm long with three flattened seeds, grey-brown when mature with a small bump.

Propagation: Direct sowing (recommended), seedlings, wildings.

Seed Info.: No. of seeds per kg: about 1,000. The tree seeds prolifically. Extract seed by cracking fruit shell and sun dry firm mature seed. Germination is good; up to 70% after 30 days. **treatment:** not necessary. **storage:** seed cannot be stored for long periods due to the high oil content.

Management: Fast-growing in high potential areas, slow elsewhere, lopping, pollarding and coppicing.

Remarks: The seed has high oil content (30%) and high protein content

(50%). The oil extract can be a strong purgative. Not recommended for intercropping due to competition with crops. There are cultural beliefs against planting this tree close to houses. Smoke from the firewood can irritate the eyes.

Dovyalis caffra
Flacourtiaceae

South Africa

Common names: Kei apple.

Ecology: A spiny shrub found in open bush and Acacia woodlands in Southern Africa, now widely planted in tropical and subtropical areas as an effective hedge that is almost goat-proof. It does well above 1,200m. Prefers deep well-drained soils, tolerates loamy clay and is drought resistant once established. In Tanzania it is widely planted in the northern regions (Kilimanjaro and Arusha) as a live fence.

Uses: Live fence, fruit (jam), ornamental, bee forage.

Description: A thorny evergreen shrub, usually 3-5m. **bark:** with strong spines to 6cm. **leaves:** thin, shiny dark green to 5cm, tip is rounded or notched. **flowers:** male and female flowers on different plants, male flowers cream yellow in dense clusters, many stamens. **fruits:** round, orange-yellow, to 4cm, soft sweet flesh, up to 20 seeds within.

Propagation: Seedlings, direct sowing.

Seed Info.: No. of seeds per kg: 27,000-47,000. 50 kg of fruits yield 1 kg of seed. **treatment:** not necessary. **storage:** seed does not store. Sow fresh seed for best germination results. Germination in 18-20 days.

Management: Fast-growing once established, initially slow. Trim regularly to maintain a good live fence.

Remarks: In the northern regions of Tanzania, seedlings of *Dovyalis caffra* are now grown by farmers for sale as there is a high local demand for seedlings for live fencing.

Eriobotrya japonica
Rosaceae

China, Japan

Common names: Loquat.

Ecology: A small evergreen tree now doing well in the Tanzanian highlands, 1,500-2,400m. It is drought resistant once established, but prefers moderate to high rainfall. Very commonly planted in the Arusha and Kilimanjaro areas.

Uses: Firewood, poles, posts, carving, food (fruit), bee forage, shade, ornamental, mulch, windbreak, jam, syrup (fruit), boundary marker (Arusha, Kilimanjaro).

Description: A compact tree to 7m, branching close to the ground. **bark:** grey and rough, young stems hairy. **leaves:** stalkless, dark green, shiny above, woolly hairs below, to about 35cm long, the tip pointed and the edge slightly toothed, young leaves paler, foliage in upward pointing tufts. **flowers:** cream-white, scented, in pyramidal tufts at the end of branches, flower buds covered with golden-brown hairs. **fruits:** yellow, egg-shaped to 3cm, brown-black seeds inside, flesh acid-sweet to taste.

Propagation: Direct sowing, seedlings, wildings.

Seed Info.: No. of seeds per kg: about 600. **treatment:** not necessary. **storage:** seed does not store well. It should be sown while still fresh.

Management: Fairly fast-growing, pruning.

Remarks: Grafted trees are available, they make stronger growth, remain smaller but mature and produce fruits faster. Seeds are poisonous and should be removed before cooking.

Euphorbia tirucalli
Euphorbiaceae

Indigenous

Common names: Finger euphorbia. **Swahili:** *utupa, mwasi.*

Ecology: A succulent shrub frequently planted as a *boma* hedge in dry areas but also found as a tree. In Tanzania it is common in livestock rearing areas where it is planted as a *boma* live fence. (Arusha, Dodoma, Mwanza and Singida).

Uses: Firewood, medicine (young branches), fish poison (latex), live fence, boundary marker.

Description: A dense straight-stemmed tree to 6m or more, the branchlets are smooth-green, cylindrical in dense masses. **leaves:** small, present on young stems, soon dropping. **flowers:** yellow-cream, small in dense clusters. **fruits:** three-part capsules, hard, purple-green, less than 1cm across.

Propagation: Cuttings.

Seed Info.: Not important.

Management: Fast-growing, coppicing, trim and top prune to make a hedge.

Remarks: Latex is very poisonous and dangerous to the eyes. Human milk is said to be a remedy if the latex gets into the eyes. Medicine from the plant must be used with extreme care due to high toxicity.

Gliricidia sepium
Papilionoideae

Central America, Mexico

Common names: Mother of cocoa, Tree of iron, Mexican lilac, Quick stick.

Ecology: It grows in a variety of soils, both acidic and low in fertility, mainly in humid coastal lowlands or lake basins, 0–1,600m in Tanzania.

Uses: Firewood, charcoal, posts, fodder (leaves, shoots, pods), bee forage, mulch, green manure, shade, ornamental, nitrogen fixation, soil conservation, soil improvement, live fence, green firebreak.

Description: A leafy shrub-like tree growing up to 8m, the trunk short and twisted, to 30cm thick. **bark:** grey-light brown, smooth, cracked with age. **leaves:** fern-like with many pointed leaflets on the stalk to 25cm, hanging down. **flowers:** pretty, mauve-pink, centre yellow, grow on the woody stem. **fruits:** pods, thin and flat to 15cm long, yellow-grey then black when dry, 3-8 seeds set free when pods breaks open.

Propagation: Seedlings, cuttings, direct sowing.

Seed Info.: No. of seeds per kg: 6,500-8,000. Germination above 90%. **treatment:** soak seed in hot water, cool overnight before sowing. **storage:** seed does not store for long, use fresh seed or cutting for best results.

Management: A fast-growing species, coppicing, pollarding, lopping.

Remarks: The Latin name means "rat killer," as a poison can be made from the leaves. Bark, roots and seeds may also contain poison. Although leaves can be fodder for goats and cattle, they are toxic to non-ruminants such as horses, donkeys and pigs. A very useful quick fence can be grown with crossed stakes which sprout easily. Wood is resistant to termites. The tree has been used to form a firebelt around forests and farms as it is fire resistant.

Grevillea robusta
Proteaceae

Southern and Eastern Australia

Common names: Silky oak, Grevillea. **Swahili:** *mgrivea.*

Ecology: It will grow on a wide variety of soils, although it does not thrive in heavy clay soils. Its climatic range is transitional and wet montane. In Tanzania it has been

planted as a nurse tree for *Olea welwitschii* in the Usa forest project, and as a commercial tree in Meru forest plantations. The silky oak is also planted as a coffee shade tree in Kilimanjaro, Arusha and Mbeya.

Uses: Timber, poles, firewood, furniture, tool handles, charcoal, fodder (leaves), bee forage, shade, mulch, green manure, windbreak, ornamental, soil conservation.

Description: A semi-deciduous tree to 20m or more with a straight trunk, angular branches and oval leafy crown. **bark:** dark grey, rough, vertically grooved. **leaves:** distinctive, fern-like, very divided, leathery pale green above, silver-grey below. Fallen leaves are slow to decompose. **flowers:** many, in one-sided golden-orange spikes, much nectar which attracts bees and sunbirds. **fruits:** dark capsules, about 1cm with a slender beak. Mature capsules split to set free 2 winged seeds.

Propagation: Wildings, seedlings.

Seed Info.: No. of seeds per kg: 70,000-120,000. The species is a prolific seeder, but the seed is difficult to collect. There is a period of only 2-3 days between seed maturity and dispersal by wind; only mature seeds are useful. Germination rate varies from 30%–90%. **treatment:** not necessary. **storage:** mature seed can be stored for up to three months.

Management: Moderate to fast-growing. Pollarding, lopping, coppicing and pruning. Young trees coppice well.

Remarks: The species is important for farmers as a general utility timber and dry season fodder. Relatively easy to establish and manage. The tree grows well with food crops if pruned and pollarded. Lateral roots can also be pruned to reduce competition with crops.

Leucaena leucocephala (L. glauca)
Mimosoideae

Central America

Swahili: *mlusina.*

Ecology: In Tanzania it was introduced on experimental basis in Morogoro (Sokoine University of Agriculture) where it proved a success as an agroforestry species. Now it is used in several areas in the country. *Leucaena* grows best at 0-1,600m altitude in full sunlight and in well-drained neutral or calcareous soils. It does not tolerate acidic soils. Needs at least 600mm rainfall. It develops a deep taproot even as seedling.

Uses: Fodder (leaves and shoots), mulch, green manure, soil improvement, soil conservation, firewood, charcoal, bee forage, nitrogen-fixation, shade, ornamental, live fence.

Description: An evergreen shrub or tree 5–20m depending on the variety, medium leafy canopy. **leaves:** compound alternate with many leaflets, each thin and pointed to 1.5cm, leaves and leaflets fold up with heat, cold or lack of water. **flowers:** white, round heads about 2cm across on a long stalk. **fruits:** numerous bunches of thin, dry, pods 10–15cm, persisting on the tree, releasing 12–25 hard, shiny brown seeds.

Propagation Seedlings, direct sowing, root suckers.

Seed Info.: No. of seeds per kg: 13,000–34,000. The species is a prolific seeder. Germination rate: 50–85% within 8 days. **treatment:** soak in hot water for 2 minutes or nick seed coat with a knife to improve germination. **storage:** properly dried seeds can be stored for several years.

Management: Very fast-growing, pollarding, lopping, coppicing.

Remarks: If not properly managed in areas of high rainfall it becomes a weed due to its prolific seed produc-

tion. Livestock feed should not contain more than 20% of *Leucaena* as the mimosine in the leaves can cause hair loss and stomach problems. Root nodules are very active in fixing nitrogen under suitable conditions. The *Leucaena* psyllid, *Heteropsylla cubana*, has recently appeared as a serious pest on *Leucaena leucocephala* in East Africa. Varieties which are resistant to the pest are being developed. *L. diversifolia* has also shown some resistance to the psyllid.

Morus alba (M.indica, M. alba var. indica)
Moraceae

China

Common names: White mulberry. **Swahili:** *mforsadi, mfurusadi.*

Ecology: It has been widely planted in Tanzania for its edible fruits, including drier areas of the country as it tolerates drought and heat once established. It does better in moist climate up to 2,000m, and commonly planted in Arusha and Kilimanjaro regions where it is frost resistant.

Uses: Firewood, timber, tools, food (fruit, leaves), fodder (leaves, shoots), bee forage, soil conservation, ornamental, shade, windbreak, live fence, silkworms (leaves).

Description: A small tree, about 5m, bole rarely straight, soon branching to rounded crown. **bark:** smooth pink-grey when young, long lines of lenticels. Branchlets red-brown hang low. When cut, latex spills out. **leaves:** very variable even on the same branch, broadly ovate to heart shaped or 3 lobed, 3 clear nerves from the base, 5-15cm long but usually small. Leaf base cordate, often unequal sided, edge coarsely toothed, tip pointed. Some hairs on both sides but leaves feel smooth above. A leaf stalk to 5cm. **flowers:** male and female, often on separate branches, tiny green-white flowers on hanging spikes about 1cm, few or no hairs. **fruits:** compound, to 2cm long with white-yellow-pink sections, may be dark red to black on one side. Edible, sweet and juicy but rather tasteless.

Propagation: Seedlings, cuttings.

Seed Info.: Poor germination. No. of seeds per kg: 325,000-700,000. **treatment:** soak in cold water for 48 hours. **storage:** can be stored a long time if kept cold.

Management: Fast-growing especially when grown from cuttings.

Remarks: Leaves are food for silkworms. The tree can be used as a hedge or to stabilize slopes.

Olea capensis subsp. welwitschii (O. welwitschii)
Oleaceae

Indigenous

Common names: Loliondo, Elgon olive. **Swahili:** loliondo

Ecology: A tree with attractive timber found in Angola, Zambia, Tanzania and Uganda in lowland rainforest to upland dry evergreen forest, 750-2,000m. In Tanzania, found mainly on the south-eastern slopes of Mt. Meru and scattered on the slopes of Kilimanjaro.

Uses: Firewood (branches), timber (furniture), veneers, medicine (bark).

Description: A tree with a straight bole and small crown, can reach up to 25m. **bark:** pale grey to white and fissured vertically. **leaves:** opposite, large (15x15cm), the tip drawn out and pointed, on a stalk to 3cm (not white below, contrary to *Olea africana*). **flowers:** small and white, in profuse sprays to 8cm long. **fruits:** narrow, oval and

small, dark green when mature, remaining on the tree.

Propagation: Seedlings, wildings.

Seed Info.: No. of seeds per kg: 3,100-3,500. Cracking seed coat and removing it improves germination rate. Germination in 35-90 days. **treatment:** soak seed in cold water. **storage:** seed can be stored up to three months but only if dried seed is stored in airtight containers and kept cool.

Management: Slow-growing, lopping, pollarding and coppicing.

Remarks: The tree has a very valuable termite resistant timber and should be well managed. Timber exploitation if not well managed will lead to the tree becoming rare. In Tanzania it was established in plantations in Usa, but today the plantation is totally destroyed by game (elephant browsing). However if the intention is to plant *Olea welwitschii*, the experience has shown that it is tolerant to shade when young and grows best when planted alongside other trees—*Grevillea robusta* in Tanzania.

Persea americana
Lauraceae

Tropical America

Common names: Avocado pear. **Swahili:** *mwembe mafuta, mparachichi.*

Ecology: Best grown in deep fertile sandy loams, but will grow in a wide variety of soils provided they have good drainage. The climatic range is moist plateau, wet lowland and transitional wet montane. In Tanzania it is planted by farmers in the northern areas and along the coast, 0-2,200m. It is also a horticultural tree in most agricultural centres in the country.

Uses: Food (fruit), oil (cosmetics), shade.

Description: A densely leafed evergreen tree to 10m. **bark:** grey-brown. **leaves:** large, alternate, to 20cm long, glossy dark green above, veins very clear, young leaves pink then bright green. **flowers:** small and abundant in large terminal heads, pale yellow, only one in 5,000 producing fruit. **fruits:** large, round to pear-shaped, hanging heavily on the tree, the central seed surrounded by a thick layer of yellow-green flesh.

Propagation Grafting materials (improved varieties), seedlings, wildings, direct seeding.

Seed Info.: No. of seeds per kg: about 15. Germination is good and takes about 6 weeks. **treatment:** not necessary. **storage:** use fresh seed.

Management: Requires no management once established, can be side pruned to obtain desired shape. Fast-growing.

Remarks: The fruit is very nutritious, rich in fat, protein and vitamins. Bark, leaves and seeds are toxic to browsing livestock. Difficult to intercrop due to its dense shade but beans can be planted with young trees. It also competes for nutrients through its dense shallow root system. Trees growing under good conditions may need stimulation to form flowers and fruit. Cut the roots in a trench around the tree or narrowly ringbark the trunk. There are some 300 named varieties of Avocado and grafting is necessary to maintain quality.

Psidium guajava
Myrtaceae

South and Central America

Common names: Guava. **Swahili:** *mpera.*

Ecology: In Tanzania it is grown mainly along the coast at present, but village conditions over much of the interior are equally suitable. It grows at most altitudes in a variety of soils and is drought hardy but cannot withstand waterlogging.

Uses: Firewood, tool handles, posts, food (fruit, jam, jelly, juice), medicine (bark, leaves, roots), shade, soil conservation, live fence.

Description: A small evergreen tree to 8m, branching irregularly. **bark:** smooth light brown, young shoots 4-sided. **leaves:** opposite, oval, side veins clear and parallel, hairy below. **flowers:** white, 1-3 together, many stamens, each about 2cm across. **fruits:** yellowish, rounded and heavy to 6cm, the calyx lobes persistent. Flesh gritty, sweet, pink, white or yellow, hard angular seeds within. Bats distribute seed.

Propagation: Seedlings, wildings, root suckers, direct sowing.

Seed Info.: No. of seeds per kg: about 500,000. **treatment:** not necessary. **storage:** seed can be stored.

Management: Fast-growing, pollarding, lopping, pruning, coppicing.

Remarks: The tree may become a weed on good sites, very often colonizing unused sites. It is best planted away from crops due to competition. Trees begin to bear fruit after 2 years and continue fruiting up to 30 years. Improved varieties (fruit size and quality) exist. The fruit are rich in vitamin C. The wood is termite-resistant.

Schinus molle
Anacardiaceae

Peru, Andes

Common names: Pepper tree, Peruvian mastic. **Swahili:** *mpilipili.*

Ecology: An evergreen tree commonly planted in dry warm climates throughout the world and in most districts of Tanzania. Almost naturalized in places. Tolerant of most soils including both dry sands and black cotton, 0-2,400m. Extremely drought resistant once established. Reaches maturity in less than 20 years.

Uses: Ornamental, shade, firewood, charcoal, posts, spices (fruits, leaves), medicine, bee forage, soil conservation, windbreak, gum, live fence.

Description: A tree with weeping foliage to 15m, the trunk short, the crown spreading. **bark:** dark brown, peeling, very sticky latex forms if the bark is damaged. **leaves:** compound to 30cm, many narrow leaflets to 7cm, with a peppery smell if crushed. **flowers:** very small, green-yellow. **fruits:** hanging on female trees, small round berries green to red then black, edible.

Propagation: Seedlings.

Seed Info.: No. of seeds per kg: 31,000–44,000. Germination rate 40%–80%. Sun-dried fruit are pounded in a pestle and mortar, then winnowed to separate the seeds from the fruit pulp. **treatment:** not necessary. **storage:** seed can be stored, add insecticide.

Management: Pollarding, lopping and coppicing.

Remarks: The tree should not be planted too close to buildings due to falling branches as the tree ages. It is shallow-rooted and liable to be blown over. The wood is termite-resistant.

Sesbania sesban (S.aegyptiaca)
Papilionoideae

Indigenous

Common names: Sesbania, river bean.

Ecology: One of many useful African *Sesbania* spp. which survive waterlogging and fix nitrogen. It is found on stream banks and beside seasonal ponds. It tolerates acid and saline soils. In Tanzania it is one of the promising species being used in the community forestry programmes for soil conservation and reclamation.

Uses: Nitrogen-fixation, firewood, poles, fodder (leaves), soil conser-

vation, fibres (young stems), soap (leaves).

Description: A deciduous, short-lived shrub up to 8m tall. **bark:** red-brown, young shoots hairy. **leaves:** compound to 12cm long, each leaflet to 2cm oblong, tip notched, narrow. **flowers:** pale yellow, speckled maroon in few-flowered sprays to 15cm long. **fruits:** abundant bunches of thin pale brown pods with separated sections so seeds rattle within.

Propagation: Wildings, direct sowing.

Seed Info.: No. of seeds per kg: about 110,000. The species is a prolific seeder with a germination rate of 65% in about 16 days. **treatment:** not necessary, but hot water then soaking for 24 hours can increase the germination rate. **storage:** seeds can be stored for long periods.

Management: Very fast-growing, pruning, short rotation, coppice when young.

Remarks: Genetic diversity allows for a certain end-use selection (e.g. for uses, management and soil types). The species harbours rootknot nematodes. It has great potential for intercropping on small farms and for fallow improvement.

Tipuana tipu (Machaerium tipu)
Papilionoideae

Bolivia, Brazil

Common names: Tipu tree, pride of Bolivia.

Ecology: An attractive flowering tree. It is drought-resistant, tolerating a wide variety of soils including black cotton, in Tanzania 1,200-2,200m.

Uses: Ornamental, firewood, charcoal, timber, poles, fodder (leaves), bee forage, shade.

Description: A large, spreading, semi-deciduous shade tree to 20m, but occasionally to 30m, with light spreading crown. **bark:** red-brown trunk, fissured and flaking with age, bark on the branches grey and cracked, sap from cut branches red and sticky. **leaves:** compound, alternate leaflets light green, each narrowly oblong to 5cm, tip round, often notched, base round on a short stalk. **flowers:** very many in long, loose sprays, each with wavy yellow-orange petals. **fruits:** unusual for legume family, the only genus with single seeded, flat winged fruit, yellow-green at first, looking like blossoms, later grey-brown, fibrous, staying on the tree for a long time.

Propagation: Seedlings, wildings, direct sowing.

Seed Info.: No. of seeds per kg: 1,600-2,700. Good germination rate, 90% and over. **treatment:** remove wings. **storage:** at room temperature, the seeds can be stored for up to three months.

Management: Fast-growing, pollarding, lopping, coppicing.

Remarks: The tree is shallow rooted so it should not be planted too close to buildings as it is likely to be blown over by wind.

Trema orientalis (T. guineensis)
Ulmaceae

Indigenous

Common name: Pigeon wood. **Swahili:** *mgendagenda.*

Ecology: A small, short-lived tree, widely distributed in Asia and Africa, 0-2,000m in higher rainfall areas. It is found in riverine forest or forest margins as a pioneer which quickly invades clearings and disturbed soils.

Uses: Firewood, charcoal, poles, fodder (leaves, pods, seeds), bee forage, shade, ornamental, nitrogen-fixation, mulch, soil conservation, black dye (bark), brown dye (leaves), oil (seed).

Description: A shrub or much branched tree to 12m. **bark:** light grey, smooth, branchlets hairy. **leaves:** alternate along drooping branchlets, to 14cm long, rough and dull above,

hairy below, the edge finely toothed all round, the blade unequal-sided. **flowers:** small, yellow-green, separate male and female flowers. **fruits:** small, round and fleshy, black when ripe 4-6mm, containing one black seed in green flesh.

Propagation: Seedlings, cuttings.

Seed Info.: No. of seeds per kg: 370,000. Germination rate is about 30%. **storage:** can retain viability for a few months.

Management: Very fast-growing, coppicing.

Remarks: A host tree for many butterflies, and the fruit attracts birds. It is a very fast-growing tree but the timber is poor. It does not compete with crops. Medicine from the leaves is reported to be an antidote to poison in general.

APPENDIX 2

Some important fodder grasses, legumes and trees

Grasses

Elephant grass/Napier grass
Pennisetum purpureum

Common Names: Elephant grass, Napier grass
Swahili: *Majani tembo (Matete)*
Characteristics: Napier grass is a tall (up to 3m), deep rooted grass, similar in appearance to sugarcane. Potentially very high yielding under favourable conditions. Drought resistant when established because of deep root systems. Ideal for contour planting to control erosion. Woody stem if let to grow tall.
Uses: Green fodder (cut-and-carry) and silage.
Establishment: Stem cuttings or root splits. Stem cuttings should include at least three nodes. When planting stem cuttings, two nodes should be covered with soil, the third being exposed.
Harvest: Harvest when the grass has reached a height of 1–1.5m. Cut 10cm from the ground.

Guatemala grass
Tripsacum laxum

Common Name: Guatemala
Swahili: *Guatemala*
Characteristics: Large tufted perennial grass. Prefer moist and light textured soils. Relatively poor tolerance to drought. Similar to Napier grass but not so ideal to hold soil as it does not spread as well laterally. Can be left standing for fodder in late dry season as it does not become woody stemmed like Napier grass.
Uses: Green fodder (cut-and-carry) and silage. Wilt before feeding.
Establishment: Stem cutting and root splits.
Harvest: Harvest when the grass has reached a height of at least 1-1.5m. Cut 10-15cm from the ground.

Giant setaria
Setaria sphacelata var. splendida

Common Name: Setaria
Swahili: *Setaria*
Characteristics: Tufted perennial grass which prefers temporary waterlogged soils and areas with reasonably high rainfall. Not drought resistant. Similar to elephant and Guatemala grass. Retains high feed value late into dry season.

Uses: Green fodder (cut-and-carry) and silage.
Establishment: Roots splits.
Harvest: First harvest at a height of approximately 1m. Cutting interval 5-10 weeks. Cut 10-15cm from the ground.

Rhodes grass
Chloris gayana

Common Name: Rhodes grass
Characteristics: A tufted perennial that can reach a height of 1m. Provides good grazing, although it must be replanted after 3-4 years. Adapted to a wide range of soils but does not withstand water-logging. Drought resistant. Withstands high stocking rates and mixes well with legumes. Not ideal on contours because of lower yield compared to elephant or Guatemala grass.
Uses: Green fodder, hay and direct grazing
Establishment: Seeds, sown in rows or broadcasted. Cuttings. Also spread naturally.
Harvest: Harvest just before flowering for hay and green fodder. Cutting interval 6-8 weeks. Cut 5-10cm from the ground. For grazing management it should be allowed to establish and then grazed to prevent flowering, as the nutritive value declines rapidly towards maturity.

African foxtail/Buffalo grass
Cenchrus ciliaris

Common Names: African foxtail, Buffalo grass
Characteristics: A tufted perennial that can reach a height of 1-1.2m. It is adapted to a wide range of soils but does not withstand waterlogging. Grows best in light textured soils in medium to low rainfall areas. Deep rooted and very drought resistant. Difficult to eradicate. Forms seed head early thus loses feed value. Seed head is undesirable as feed. Not for use on contours.
Uses: Preferably for permanent pastures, but can also be used as green fodder and hay.
Establishment: From seeds, sown in rows or broadcasted. Also spread naturally. Slow establishment.
Harvest: For hay and green fodder, harvest at beginning of flowering stage, 2-3 months. Cut 10cm from the ground. Buffalo grass can stand considerable grazing once it is established.

Molasses grass
Melinis minutiflora

Common Name: Molasses grass
Characteristics: Tufted perennial grass up to 1.5m high with many nodes and branches. Occurs naturally in bush, forest edges, grassland and steep rocky slopes. Good feed value late in dry season. Does not form seed head early and can be established in various conditions but prefers cool and moderately moist climate.
Uses: Hay, green fodder (cut-and-carry).
Establishment: Seeds, broadcasted or drilled. Root splits.
Harvest: Beginning of flowering stage, 2-3 months.

Maasai love grass
Eragrostis superba

Common Name: Maasai love grass
Characteristics: Densely tufted perennial grass that grows up to 1m. Drought resistant. Prefers sandy soils but occurs also on clay loams and clay. It gets stemmy and unpalatable near maturity and its maturity value drops.
Uses: Direct grazing.

Establishment: Seeds. Can be collected easily by stripping the ripe panicles.
Harvest: Maasai love grass should not be grazed until well established after seeding.

Makarikari grass
Panicum coloratum var. makarikariense

Common Name: Makarikari grass
Characteristics: Perennial grass that grows around 1.5m high. Stands waterlogging but is also relatively drought resistant. Used for erosion control on terraces.
Uses: Direct grazing. It should be grazed lightly in the first year, but can withstand heavy stocking when established. Hay.
Establishment: Cuttings and seeds. Shallow sowing (1 cm) on soils with poor structure. In better soil 2-3cm.
Harvest: Beginning of flowering stage.

Legumes

Green leaf desmodium
Desmodium intortum

Common Name: Green leaf desmodium
Swahili: *Fundofundo*
Characteristics: Large perennial legume with many branches, often red-brown stem.
Uses: Green fodder, hay, silage and direct grazing. Control due to bloat 1/3 interval of total rotation. Interplanting with elephant grass and Rhodes grass.
Establishment: Seeds, mature stems.
Harvest: First harvest after 2 months. Cutting interval 4-6 weeks. Cut 30cm from the ground.

Silver leaf desmodium
Desmodium uncinatum

Common Name: Silver leaf desmodium
Swahili: *Fundofundo*
Characteristics: Large perennial legume with trailing stems up to 5m.
Uses: Direct grazing, hay, green fodder, silage, interplanting with elephant grass and Rhodes grass.
Establishment: Seeds, mature stems.
Harvest: After two months, cutting interval 4-6 weeks. Cut 30cm from the ground.

Lucerne
Medicago sativa

Common Name: Lucerne
Swahili: *Alfa alfa/Lucerne*
Characteristics: Erect perennial legume with deep root system.
Uses: Green fodder (1/3 of total rotation), hay.
Establishment: Seeds.
Harvest: After 2-3 months, cutting interval 4-6 weeks. Cut 10cm from the ground.

Velvet bean
Stizolobium deeringianum

Common Name: Velvet bean
Characteristics: A twining annual legume. If unsupported, the twining stems will spread out over the ground, producing large quantities of vegetative material. Very drought resistant.
Uses: Usually grown in crop rotation for fodder. Can stand light direct grazing.
Establishment: Seeds.

Siratro
Macroptilium atropurpureum

Common Name: Siratro
Characteristics: A trailing perennial legume that roots at the stem nodes. Fairly hardy and drought resistant. Adapted to a wide range of soil and can also grow in low rainfall areas. Persists well under grazing.
Uses: Direct grazing, green fodder, hay, silage.

Establishment: Seeds.
Harvest: After 2 months, cutting interval 4–6 weeks.

Fodder (multipurpose), trees and shrubs

Further information about fodder trees is found in Appendix 1.

- *Leucaena diversifolia*
- *Leucaena leucocephala*
- *Calliandra calothyrsus*
- *Gliricidia sepium*
- *Sesbania sesban*
- *Tipuana tipu*
- *Morus alba*

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The Swedish International Development Cooperation Agency (Sida) has supported rural development programmes in countries in Eastern Africa since the 1960s. It recognizes that conservation of soil, water and vegetation must form the basis for sustainable utilization of land and increased production of food, fuel and wood.

In January 1998, Sida inaugurated the Regional Land Management Unit (RELMA) based in Nairobi. RELMA is the successor of the Regional Soil Conservation Unit (RSCU), which had been facilitating soil conservation and agroforestry programmes in the region since 1982. RELMA's mandate is " To contribute towards improved livelihoods and enhanced food security among small-scale land users in the region", and the geographical area covered remains the same as previously, namely, Eritrea, Ethiopia, Kenya, Tanzania, Uganda and Zambia. RELMA's objective is to increase technical know-how and institutional competence in the land-management field both in Sida-supported programmes and in those carried out under the auspices of other organizations.

RELMA organizes training courses, workshops and study tours, gives technical advice, facilitates exchange of expertise, and initiates pilot activities for the development of new knowledge, techniques and approaches to practical land management.

In order to publicize the experiences gained from its activities in the region, RELMA publishes and distributes various reports, training material and a series of technical handbooks.

About this book:

This is a manual that highlights conservation methods and techniques suitable for Tanzania. It provides extension staff and farmers with basic knowledge on the integration of soil conservation in farm management. Adequate coverage is made on soil erosion, its effects and causative factors. This is in addition to the control measures which encompasses physical, biological and cultural techniques of soil conservation. Although the manual is developed for the SCAPA project in the Arusha region of Tanzania, it is also relevant not only for the other parts of thr country, but also to the rest of the East & Southern Africa region.

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