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UGANDA LAND RESOURCES MANUAL

A guide for extension workers

Charles Rusoke
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Top: A herd of Banyankole cattle grazing on natural pasture
Middle: A productive banana plantation
Bottom: Excavation bench terraces

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Foreword

I am pleased to be able to offer a few words by way of a Foreword for this publication which is aimed at improving the availability of reading materials for our extension workers. The policy of the Government of Uganda is to rapidly achieve significant improvements in land productivity, this being the main strategy for reducing poverty and making significant improvements in the standard of living for the majority of the people. The agricultural industry is seen as the key sector for generating the resources to provide the necessary impetus for economic growth. This calls for a vastly improved and modernized agricultural sector that is able to utilize, and respond to, new technology and changing markets (both local and international). A modern agricultural system will be expected to contribute to the national economy through increased food security, income generation and the promotion of sustainable use of natural resources.

Over 6% of Uganda's population are classified as poor, and 20% as very poor (where 'poor' is defined as those who earn below two-thirds of the overall per capita income, and 'very poor' those who earn below one-third of the per capita income). The per capita income was only US$ 110 in 1995. Most of the poor people (92%) are found in the rural areas and earn their living from an increasingly unproductive agricultural sector that produces little or no surplus for cash income. To cope with the decline in production, farmers are forced to clear more land, often targeting steep hillsides, valley bottoms, wetlands and forested areas.

The process of modernization must include a shift from mere subsistence production to a market-oriented agricultural industry that will generate additional (non-traditional) export products for the eastern and southern Africa region, Europe and other markets, besides adequately meeting local demand. Horticultural development deserves special mention because of its potential for income generation at household and national levels. Uganda has vast water resources and an excellent climate for horticulture. Concrete action needs to be taken now to initiate a focused horticultural production system.

The improved production programme must also include proper conservation of the natural resources. Notably, the following must be included as integral parts of the land development and management programmes of the future:

- Soil and water conservation and the maintenance of soil fertility and land productivity. This is a major theme of this publication.
- Integration of livestock in the farming systems.
- Agroforestry and farm forestry to supply multiple needs at the farm level and beyond.

All government extension officers, researchers and non-governmental organizations (NGOs) should work closely with farmers to improve land-, crop- and animal-husbandry practices. The main aim is to achieve increased and sustained productivity of the available land, leading to significant growth in agricultural incomes, besides ensuring food security for the communities involved.

I wish to commend the authors for their efforts, and particularly for having come together from different departments and different specialities, to produce this guide. Other subject areas require the same kind of collaborative effort to produce reading materials for our extension workers and farmers. Finally, many thanks to the Regional Land Management Unit of Sida for supporting the production of this publication. I hope it will be of use to the intended readers.

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MAAIF

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The team also travelled to the following Districts: Mpigi, Masaka, Mbarara, Kabale, Bushenyi, Kasese, Kabarole, Mubende, Tororo, Mbale, Pallisa, Kapchorwa, Kumi, Soroti, Lira, Apac and Arua. Government officers and NGOs were consulted. The NGOs contacted included CARE, World Vision, IUCN Mt. Elgon Conservation Project, and ICRAF-Kabale. The team is indebted to all the people who gave their time during the sometimes lengthy discussions that took place. Useful comments on a first draft of the manual were made by the participants of the workshop held in Jinja.

This Land Resources Management Guide is a collective effort of all the people who contributed to it in one way or another. The accuracy of the content, however, remains the responsibility of the joint authors.

Preface

Uganda's population now stands at 19.8 million. At an annual growth rate of 2.5%, the population is projected to have risen to 21 million by the year 2000. This increased population pressure is resulting in the use of marginal lands for cultivation, deforestation, over-cultivation and general overuse of the land resources, decreased land productivity due to erosion and declining soil fertility, and the degradation of water resources. To combat these ills, extension workers and farmers require practical knowledge on better land management practices.

The main objective of this guide, therefore, is to contribute to the planned modernization of agriculture in Uganda through better management of land resources. This will in turn enhance food security and self-sufficiency in raw materials for agro-processing industries, and produce surpluses for export.

The specific objectives of the manual are to:

- Highlight the need to develop sustainable farming practices, including the enhancement and maintenance of adequate levels of soil fertility, and the full utilization of available rainfall runoff for production
- Provide a practical guide for giving effective land-management advice to farmers
- Provide simple reference notes for extension agents, students, NGOs and other institutions
- Create a basis for establishing and improving regulatory by-laws that are appropriate to land-resource management at the local level.

Extension workers are the main target group for this manual. However, it will also be useful in training programmes, mainly in colleges. Some farmers will also find it useful during their daily agricultural activities. The manual will also be useful for civic leaders and policy makers in local councils in their efforts to formulate practical by-laws for better management of their land resources.

1. Introduction

1.1 Background

Agriculture is the mainstay of Uganda's economy, in 1994 accounting for 49% of gross domestic product (GDP) as well as 80% of employment and over 90% of commodity exports. It provides raw materials for agro-based industries and provides markets for the manufacturing industry. Out of the 49% contribution to GDP by agriculture, food crops alone account for 71%, export crops 5%, livestock 17%, fisheries 4%, and forestry 3%. Agriculture also contributes as much as 80% of total employment.

Agricultural productivity in Uganda has been declining mainly due to a decrease in soil fertility, soil erosion and generally poor land-management practices. For instance, yields of bananas have declined from an average of 8.5 tonnes per hectare in 1970 to 5.7 tonnes per hectare in 1996, leading to the opening up of more virgin land for cultivation, and in turn subjecting it to overuse and degradation. It is estimated that land degradation has resulted in annual losses of up to 12% of GDP. The value of soil lost to erosion alone has been conservatively estimated at US$ 400 million per annum (NEAP 1991). This has a serious (but unaccounted for) effect on the total GDP.

Food security means access (both physically and financially) by all the people in a given location to adequate food, both in quantity and quality, at all times. It can be achieved through the ability to grow one's own food and/or to purchase it from an efficient marketing and distribution system. In the Ugandan context, the achievement and maintenance of food security requires the attainment and maintenance of national-level food self-sufficiency that is based on a broad variety of crops. It should emphasize improved production of the well-adapted traditional food crops, principally bananas, sweet potatoes, cassava, millets, sorghum, beans and maize, as well as groundnuts, simsim and other oil crops. Growing conditions are also suitable for the production of a wide variety of vegetables and fruits in the different agro-ecological zones. Livestock also play a key role in the lives of the majority of the people. Improved food security must therefore include better management of livestock to improve productivity levels and ensure that land is not degraded through overstocking.

Such sustained food self-sufficiency must also accommodate the increased demand from a growing population, create significant reserves to enable the country to be tided over periods of poor rainfall, while ensuring the required quality for achieving good nutritional standards in all segments of the population. Greatly improved production technologies will be required to bring production of these crops to a level that will satisfy all subsistence needs as well as generating surpluses for local and external sale. It is also important to develop an efficient extension service that will work closely with farmers in developing and implementing the needed improvements. There must also be very strong linkages between extension and research to ensure that research remains both vibrant and relevant.

Horticulture, food processing and post-harvest handling are vital sub-sectors in the agricultural industry. They require special attention. Action points for horticultural development should include the following:

- Strong research and extension linkages to provide the necessary technical base
- Developing effective support from strengthened research and extension services with backing from both government and private sectors
- Farm-level promotion that encompasses training of extension workers and farmers, the introduction of improved methods and techniques, and a wider variety of products
- Supply of the required farm inputs at points close or accessible to the farmer, and better availability of farm credit
- The setting up of a strong market research and information programme to take advantage of the best outlets globally
- Strong linkages with Uganda Airways and other possible carriers for efficient shipment of horticultural produce to designated markets
- Other necessary infrastructure such as the development of cold storage facilities at strategic points
- Local processing of horticultural produce to increase value, reduce bulk and increase shelf life
- Appropriate policy support and legislation to back up the sub-sector.

1.2 Characteristics of smallholder agriculture in Uganda

Most agricultural activities in Uganda are carried out by an estimated 2.5 million households. On average, these households own about 2 ha each, and together account for up to 90% of the population.

Characteristics of smallholder agriculture in Uganda are:

- Very low investment from both the public and private sectors, leading to poor capital accumulation and progressive deterioration of the land.
- Lack of access to credit to facilitate acquisition of recommended technology,

and the absence of effective management to institute modern methods which would increase productivity.

- Use of rudimentary technology (with the hand hoe and machette being the most common tools), as well as minimal use of complementary inputs such as fertilizers and other agrochemicals.
- Repeated use and recirculation of low-yielding seed varieties and inferior breeds of animals and fish. It has been observed that farmers achieve between 13% and 33% of the yields attainable at research stations.
- High dependence on family labour that is largely provided by women.
- Insecure land-tenure systems which have led to a contradictory situation in which acute land fragmentation exists side by side with large tracts of unutilized cultivable land.
- Excessive dependence on rain-fed agriculture, and overuse and over-cultivation of the smallholdings leading to erosion and loss of soil fertility. Very little irrigation is practised.
- Poor and unreliable marketing systems for both agricultural inputs and outputs.
- The tendency of farmers to keep large herds of livestock, leading to overstocking and associated land degradation.
- Poor husbandry, handling and processing practices in fish farming.
- High post-harvest losses.

These negative attributes of small-scale farming should be addressed through more efficient extension services that have a range of useful messages for farmers. The aim should be to significantly improve production, attain assured food supplies, raise rural incomes, and contribute to poverty eradication.

2. Land resources in Uganda

2.1 Major agro-ecological zones of Uganda

Uganda can be divided into 4 major agro-ecological zones (Figure 1). The extension worker will be expected to advise the farming communities on various land husbandry practices, including soil and water conservation measures, that are appropriate for the specific zone in which he works.

2.2 Major farming systems in Uganda

The agricultural practices in Uganda can be classified into 9 different farming systems (Figure 2). These major agricultural practices depend on the ecological suitability of an area and farmer preferences (see Appendix I).

2.3 Forms of land degradation in Uganda

The most common forms of land degradation in Uganda are the following.

Water erosion

This is the washing away of soil by water, either in the form of sheet erosion, rill erosion or gully erosion. Water erosion is the most common and widespread form of erosion throughout Uganda. It is severe in Mbale, Kabale, Kabarole and Kapchorwa where high-altitude mountain slopes have been extensively deforested.

Wind erosion

This kind of erosion involves the removal of soil from the land surface by wind, and then its transportation and deposition in other areas. In Uganda, wind erosion is less serious than water erosion. It occurs in areas of low, variable and poorly distributed rainfall where soils remain exposed during prolonged dry seasons. These are mainly Kotido, Moroto, Soroti, Kumi and Lira Districts, and in all areas where uncontrolled bush burning is practised.

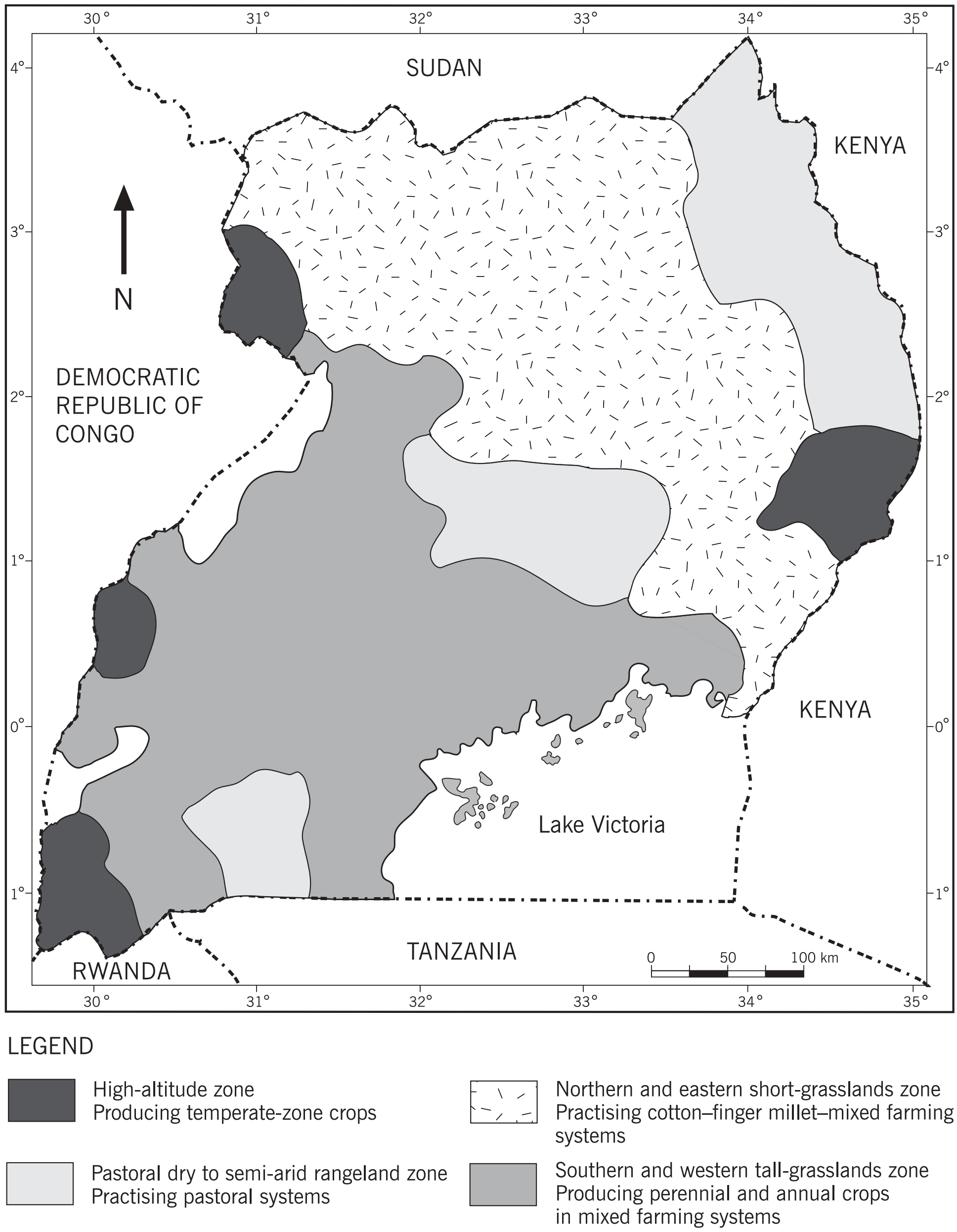


Figure 1. *Major agro-ecological zones of Uganda.*

Biological degradation

Loss of vegetation, soil organic matter and soil organisms.

Leaching

Leaching is the washing down of nutrients from the soil to a depth beyond the reach of plant roots. All areas of Uganda with sandy and loamy soils are affected by this type of soil degradation. The high-rainfall districts of Mbale and

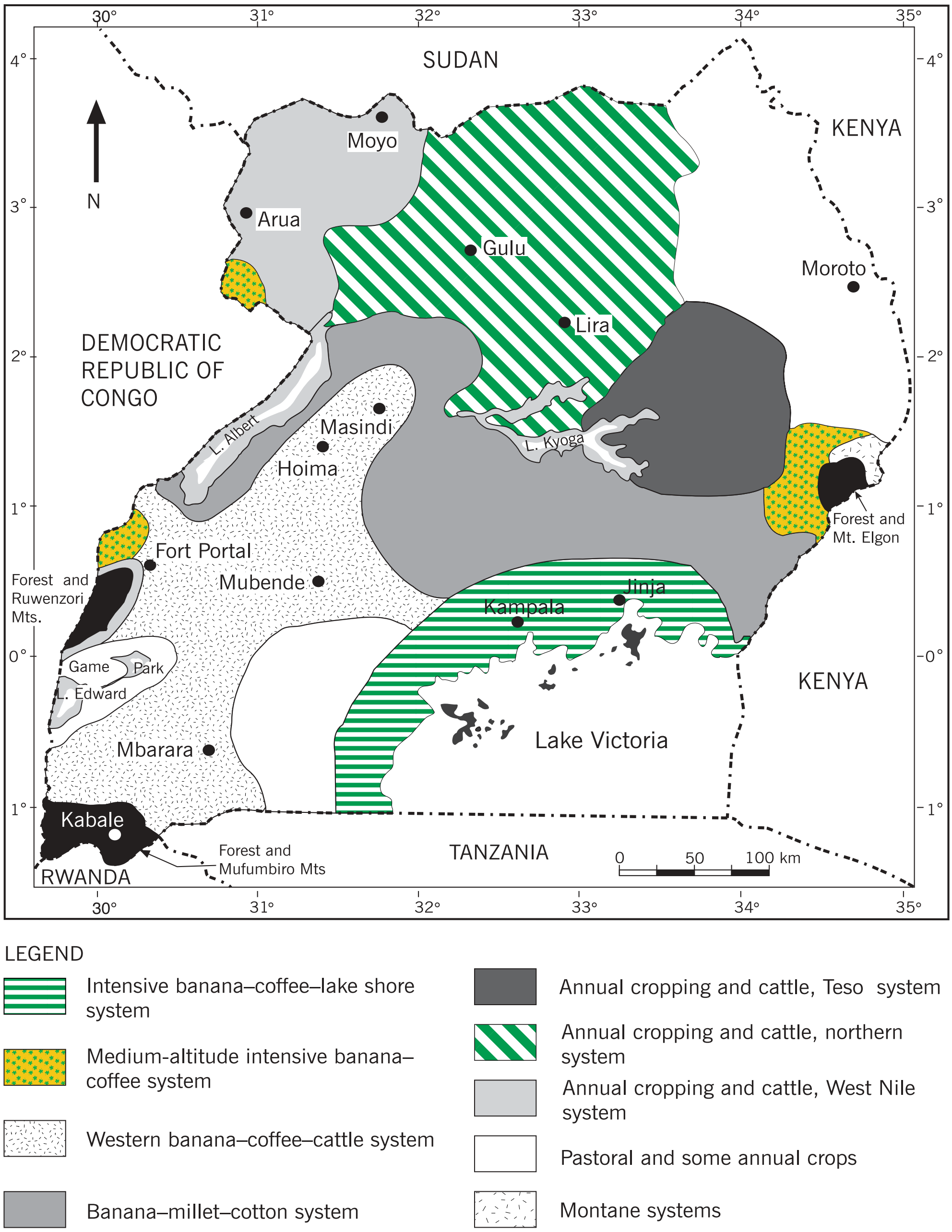


Figure 2. *Uganda farming systems.*

Kabale and the Districts surrounding Lake Victoria also experience this type of land degradation.

Change in soil structure

This is mainly due to soil compaction, seasonal fires and continuous cultivation. Soil compaction is serious in Districts that are overstocked. Examples are Moroto, Kotido, Mbarara and Northern Luwero. In Mukono and Jinja Districts, and in Kigumba where large-scale mechanized farming was introduced, symptoms of soil compaction are evident.

Salinity

This is a situation where there are excessive amounts of salts in the soil that end up impairing the process of osmosis, thus killing plants. A few soils in Uganda are saline. These are found mainly in the Semliki Valley, south of Lake Albert.

Acidity

Acidity is common in swampy areas with clay soils, e.g. in Kabale.

Waterlogging

This refers to excessive saturation of soil by water. It is a form of soil degradation common and severe in most river valleys, swamps and areas adjoining Lake Victoria and Lake Kyoga. After floods, hydromorphic soils become excessively dry, compact and crack into large lumps during the dry season.

Pollution

Chemical or biological contamination of soils through the incorrect use of agricultural fertilizers and pest-control chemicals is a minor problem in Uganda. (Indeed there is a need to increase the use of both organic and inorganic fertilizers used in crop production.) An example of pollution is provided by the cobalt deposits from Kilembe mines in Kasese District which have caused serious pollution from the smelter plant up to Lake George where most of the vegetation has been scorched, leaving extensive areas of bare soil.

Causes of land degradation

Socio-economic factors

Bad management practices are a result of ignorance, population pressure or socio-economic, cultural and political forces. For example, in Tororo, Pallisa, Soroti and Kumi Districts, cotton farmers were unable to obtain a good price for their crop in the 1970s, hence they turned to growing of paddy rice, leading to draining of the wetlands. In many areas, poor people have turned to brick making, and the resulting pits become incipient gullies. Sand excavation has brought the same result. Brick making requires a great deal of fuelwood, and this has led to deforestation.

Infrastructural development

When grading roads, murram is excavated leaving behind deep pits that serve as gully heads. The discharge of excess runoff from the roads through culverts often causes gully formation on farms.

Loss of vegetation cover is a major cause of soil erosion and land degradation, often arising from overgrazing in areas where ownership of many cattle is seen as prestigious (e.g. Nyabushozi in Mbarara, Kotido, Moroto), and from deforestation and cultivation of steep slopes. Examples of deforestation can be seen in Arua, where trees are cut for tobacco curing, and elsewhere in the country for brick making.

Physical causes

The erodibility of a soil depends on its structure and the organic-matter content. The length and the gradient of the slope also affect the amount of soil that is removed, thus erosion is severe in hilly areas of Uganda such as Mbale and Kabale Districts.

Land tenure

This is among the most important causes of accelerated soil erosion and other forms of land degradation. Four land-tenure systems exist in Uganda. They are:

- Customary land tenure
- Communal land tenure
- *Mailo* land tenure
- The leasehold system.

Customary land tenure

This is the most widespread land-tenure system in the country and the most secure one since it bestows unrestricted user and disposal rights. This system encourages land fragmentation.

Communal land tenure

Communal land tenure occurs particularly in areas where there is still plenty of land. The tenant has user rights but he has no disposal rights. The farmers therefore tend to exploit the land without developing it, especially where traditional safeguards have broken down.

Mailo *land tenure*

This system originated from the 1900 Buganda Agreement with the British through which about 49% of the most productive land in Buganda was allocated freehold to the Kabaka (King), other members of the royal family, principal chiefs and clan elders. The rest remained public land.

Leasehold system

This applies to all parts of Uganda. The land user leases land from an individual owner, or from the Government in the case of public land, and pays rent for a period of time (49, 60, 99 or 199 years). This system tends to result in the rich acquiring large parcels of land for prestige or for speculation purposes at the expense of the poor. Some rich people sublet such pieces of land to tenants who, naturally, will not make long-term investments in it because of the temporary nature of their tenancy.

General comments on land-tenure systems

The land-tenure situation in Uganda is complex and each system has inherent constraints for the promotion of land-resource conservation and the improvement of productivity. Under the *mailo* and leasehold systems, tenants and lease owners have no security over their holdings. They are subject to eviction and therefore have little incentive to invest in any form of land improvement or resource conservation. Under the communal tenure system there is no incentive for the individual to ensure that the land is used properly. The freehold system, on the other hand, leads to fragmentation as population pressure increases, and this becomes a major hindrance to the introduction of farming techniques that would reduce overall environmental degradation. Progressive and imaginative land-tenure policies are a prerequisite for better land resource management and a modern agricultural sector.

Consequences of land degradation

These are many and diverse, but generally include the following:

- Reduction of natural fertility, and reduced water-holding capacity of soils, leading to reduced crop yields, poor livestock and biomass production, and hence declining standards of living. For example, Bugerere (Mukono District) used to be a major banana growing area in Uganda, but now banana yields have decreased drastically.
- Reduction in the quality and value of the land due to soil erosion, and complete loss of cultivable land if the problem is not checked.
- Silting up of reservoirs, rivers, navigable waterways and natural drainage systems. Examples are Kagera, Manafwa and Malaba rivers, as well as Lake Kyoga. The water quality has deteriorated.
- Increase in the frequency and severity of flooding in many swampy areas, especially those adjoining Lakes Victoria and Kyoga, often because of excessive deforestation in the highland areas and the draining of swamps.
- Alteration in the aquatic environment due to siltation leads to reduction in

fish stocks and breeding grounds. It is assumed that the water hyacinth that has spread in the aquatic environments of Uganda thrives partly on the silt in the reservoirs. In turn, the water hyacinth reduces the number of fish in the reservoirs and reduces water volumes due to evapotranspiration.

- Reduction in the power-generation capacity of dams due to siltation or sedimentation.
- Salinization and acidification of swamp soils has occurred in swamps that have been drained without technical advice in Iganga, Tororo, Kumi, Soroti and Lira Districts for growing of paddy rice, and in Kabale for other agricultural purposes and dairy production.
- Loss of rainwater as runoff leading to lowering of water-tables and drying up of streams.
- Accessibility problems and damage caused by gullies.
- Loss of good soil due to deposition of silt or sand, and loss of life and homesteads due to landslides.
- Shortage of trees and tree products, and fodder for livestock.

3. Soil conservation on cultivated land

3.1 What is soil conservation?

Soil conservation is broadly defined as a set of good land-husbandry practices and techniques to protect and enrich the soil and water resources that sustain agricultural production. These activities and techniques are seen as inputs towards environmentally sound production of food, fodder, wood and other commodities. The term soil conservation is usually used as an abbreviation of 'soil and water conservation'. Soil-moisture management, drainage of surplus water, and harvesting of water under dry conditions, as well as actions to enhance soil fertility, are important aspects of conservation. The ultimate objective is to enable the farmer to attain a high production level, and to ensure that land productivity is sustained, and improved, indefinitely.

Soil conservation techniques

Any measure that helps improve the productive capacity (quality and quantity) of the soil and water resources of a given ecosystem is regarded as a soil and water conservation measure or technique. Such measures are grouped as follows:

- Agronomic and vegetative techniques
- Physical techniques.

To conserve soil and water, and to ensure sustained productivity, the following should be observed:

- Land should be protected from the hazardous impact of raindrops and wind by maintaining adequate vegetative cover
- Maintenance of a good balance between crop and livestock production systems to prevent overgrazing and other undesirable effects
- The practice of an alternative range of options that could improve benefits for farmers while also sustaining or improving the productivity of the land.

The basic conservation methods on cultivated land are the cultural and biological measures that are part of ordinary farming practices. The aim is to establish crops to cover the soil well and to maintain a good soil structure for effective water infiltration. Specific actions should also be taken to improve or maintain soil fertility and, consequently, yields. On gentle slopes, appropriate cultural and biological measures are sufficient, but on steeper slopes these measures need to be supplemented with physical measures.

3.2 Agronomic and vegetative measures

Mulching

Mulching is the act of covering the soil with dry vegetative material, such as dry grass, leaves, millet or maize stalks, coffee husks, rice husks, the pseudostems and leaves of banana plants or any such materials. Material from diseased plants should never be used for mulching as these diseases may attack crops. Mulching can be used in many crops, but is common in vegetable gardens and in coffee, banana and young tree plantations.

Mulching has the following advantages:

- It prevents or minimizes the direct impact of raindrops on bare soil, therefore reducing splash erosion.
- It reduces evaporation from the soil surface, hence conserving soil moisture.
- Water running down a slope is slowed down, thus reducing its erosive power. The lower speed of flow improves infiltration and enhances soil-moisture content.
- Wind cannot blow the soil away.
- Soil structure and soil fertility are improved as a direct effect of the organic matter in the mulch.
- Weed growth is checked.
- Useful insects and worms are encouraged to make holes in the ground, thus increasing the permeability of the soil, and also increasing aeration and water infiltration.

Cultivating along the contour (contour farming)

Contour farming is the practice of cultivating (ploughing and planting) along the contour. When a plough is used in contour ploughing, the resultant furrows also prevent water from flowing down the slope. The decreased runoff improves infiltration and permits a better retention of water and nutrients. Ploughing and planting must always be done across the slope, following the general trend of the contour lines.

Good tillage practices

It is important that suitable tillage practices are adopted. Generally, large soil clods increase the infiltration capacity of the soil. Intensive tillage (ploughing and harrowing several times) destroys the crumb structure of the soil, and should be avoided. Some tillage options are as follows:

Zero tillage

This is a practice that involves no physical tillage operations. Instead, herbicides are used to control weeds before planting or after harvest.

Minimum tillage

This is a practice where land preparation is done with minimum disturbance of the soil surface, i.e. small holes are made for each seed or narrow strips dug for planting.

The following are general guidelines for tillage practices:

- All tillage operations should be carried out along the contour
- Use the minimum number of tillage operations possible
- If possible, avoid harrowing because pulverizing of clods destroys soil structure, which can cause soil capping or sealing, thus decreasing infiltration capacity and increasing surface runoff
- Incorporate crop residues and/or animal manure into the soil during tillage operations
- Concentrate the application of the compost or manure along the planting lines to optimize the use of these valuable inputs
- Leave crop residues on the soil surface as soil cover (mulch). Do not burn!
- Avoid tilling wet soil as this causes compaction
- Use appropriate tillage tools
- Proper timing of operations helps take full advantage of the rains.

Timely planting

Crops should be planted as early as possible so that they will have covered the ground by the time the rains become heavy, thus reducing the effects of runoff and raindrop erosion.

Optimum plant cover

During planting, the correct spacing should be used to achieve optimum plant cover so that patches of bare ground are avoided. Where poor germination or poor establishment of seedlings occurs, gap filling should be done. (See Appendix II for optimum spacing of some selected crops.)

Optimum stocking rates

Improving grazing lands by planting selected grasses and legumes, coupled with keeping the right numbers of livestock in a given area (optimum stocking rate) is one of the best conservation methods in grazing lands. Details of suggested grass and legume species, including management, are given in Chapter 7.

Use of organic manures

This is the practice of using compost, green manure and farmyard manure (FYM). Besides supplying some of the required plant nutrients, this practice also improves soil structure through supply of organic matter, which in turn improves the water-holding capacity of the soil. Details about these methods are given in Chapter 4 on management of soil fertility.

Ridging or listing

Making of ridges is recommended, especially for sweet and Irish potatoes, although ridges can also be used for cotton, maize and sorghum. After harvesting, the crop residues can be buried when the ridges are broken down. In some cases, higher yields, especially of sweet potatoes, are obtained by ridging. However, care must be taken when using this method. Ridging can increase the risk of overflows after heavy or prolonged rain because the ridges are not normally perfectly graded.

To overcome the risk of erosion, tied ridging (basin listing) is recommended. Tied ridging can increase soil moisture and crop yields in semi-arid areas, but it should not be used where there is a risk of waterlogging, such as in soils with a low permeability in high rainfall zones. Another advantage is that the ridges need not necessarily be cut accurately on the contour. Instead of continuous basins (a series of tied ridges), pitting can be used in semi-arid areas and the plants planted inside the pits. Figure 3 shows how the pits are arranged in this method.

Tied ridging and pitting can easily retain the water from a 75-mm storm. Another advantage is that the ridges need not necessarily be cut accurately on the contour.

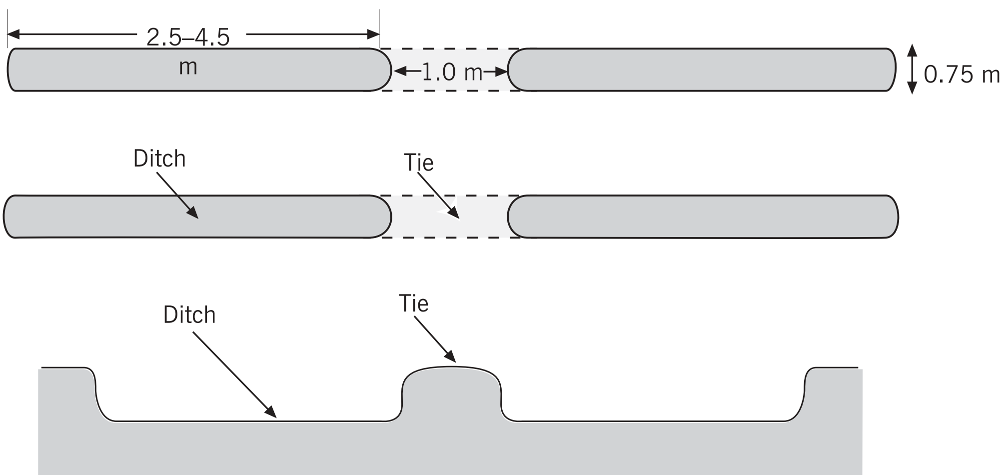


Figure 3. *Ridging or listing.*

Fallowing

Continuous cultivation, especially without proper rotations, leads to land degradation. Such land can be improved through fallowing, that is, leaving the land uncultivated for a certain period depending on type of soil and the availability of alternative land. Improved fallows can be obtained by reseeding the land with legumes which accelerate improvement in soil fertility. Fallowing results in the improvement of the organic-matter content, soil structure, fertility and soil-moisture-holding capacity.

Avoiding fires

Burning of vegetation (bush and grass fires on farms) should always be avoided. Although use of fire has some positive applications, the following disadvantages should be noted:

- The organic matter becomes ash, when it would have a greater beneficial effect if allowed to decompose slowly.
- Burning has a deleterious effect on soil fertility as organic carbon, nitrogen and sulphur are lost to the atmosphere in the process. The nutrients concentrated in the ash will be leached out quickly or are blown away by the wind, while on sloping land the ash and its nutrients are easily washed away.
- Burning destroys the humus contained in the uppermost layers of the soil, thus destroying the soil crumb structure and reducing the infiltration rate. Consequently, the rate of runoff can be significantly increased, resulting in more erosion.
- Burning exposes the soil, also increasing the potential for erosion, especially on slopes.
- Burning destroys beneficial soil organisms.

Cover crops and green manures

What are cover crops?

These are crops that are purposely planted to cover and protect the soil from exposure:

- During the off-season
- Within tree plantations such as those of oranges, bananas and coffee
- In crop fields at the beginning of the fallow period
- During breaks in the annual cropping cycle.

Cover crops are usually quick growing crops such as sweet potatoes, pumpkins, beans, cowpeas or grasses. The preferred cover crops are mostly, but not always, legumes, which are deliberately grown for the purpose of incorporation into the soil to improve its fertility.

What is green manure?

Green manure is made by incorporating leguminous plants into the soil to improve soil structure and fertility. The crop to be incorporated is grown deliberately for this purpose. Common species used in the region include *Mucuna* sp. (velvet bean), *Crotalaria ochroleuca* (sunn hemp, or *marejea*, *Cajanus cajan, Glycine javanica, Pueraria phaseoloides* and *Centrosema pubescens*. An ideal green manure crop is one that meets most of the following criteria:

- Accumulates much biomass within a short period (is quick growing)
- Nitrogen fixing
- Is deep rooting to improve soil structure and recycle nutrients
- Covers the soil quickly, thus controlling erosion and suppressing weeds
- Produces many leaves and no hard woody stems
- Is easy to establish
- Does not compete much for moisture with the food crop
- Has multiple uses such as food, fuel, fodder and control of pests.

Use of green manures

Legume cover crops such as velvet bean and sunn hemp can be intercropped with maize, or be planted after the food crop has been harvested or during the dry season. The plant material is then incorporated into the soil during land preparation. In other situations, the green manures are slashed and left as surface mulch. This also helps to check soil erosion at the beginning of the rains. To avoid competition for moisture and nutrients, some green manure crops, such as mucuna, are planted two to three weeks after planting the maize.

How to use green manures

- Incorporate green manures into the soil during land preparation. In case of high biomass turnover (as with mucuna), some of the biomass can be removed as animal fodder. The rest is chopped up into small pieces before incorporation into the soil. Some farmers prefer leaving the green manure on the surface as mulch.
- In poor soils, the green manure crop is left as cover for one or two seasons. This 'improved fallow' helps enhance soil fertility. The green manure is incorporated into the soil at the end of the fallow period to benefit the subsequent crop.

In no-till (zero tillage) systems, legumes are grown and then slashed, or are killed with a herbicide, to form a protective mulch cover. Legumes for no-till systems should have the following characteristics:

- Be low-growing or creeping herbs or small shrubs
- Be aggressive, competitive and able to outgrow weeds; that is, the legume should have rapid early growth and should retain the protective ability for the required period (slow decomposition)
- Have readily available planting material (seed or cuttings)

- Be able to improve soils (therefore able to grow well on poor soils)
- Be easy to establish in such a no-till system
- Be able to stand severe moisture stress and other difficult conditions normally encountered in the area
- Have low establishment and management costs
- Be easy to eradicate using a relatively safe herbicide to form a protective mulch which does not interfere with the operation of no-till equipment
- Should not host pests and diseases, and should not become weedy.

Wash-stops

These are cross-slope barriers that are established to slow down and distribute rainfall runoff down a slope. Water will infiltrate the strip and and the suspended soil will be deposited above the barrier. Wash-stops initiate the development of bench terraces.

Below are several types of wash-stops for cultivated land.

Grass strips and bush hedges

The following are examples of materials that can be used:

- Sisal hedges
- Bush hedges, for example, leucaena and calliandra
- Napier, vetiver and other grass hedges planted between ploughed land on the contour.

These wash-stops are made as follows:

- Determine a series of contours along the slope. As a rule of thumb, if the soils are deep, the vertical drop from one contour to the next is 1.5–2.0 metres (less in shallow soils)
- Leave strips of uncultivated land on each contour line to form strips 0.5–1.0 m wide
- Plant a perennial high-yielding fodder grass along the strip, choosing an intra-row spacing that will ensure a closed hedge in the strip.

These wash-stops can also be graded where drainage is a requirement.

Trash line wash-stops

A trash line is formed by arranging or heaping trash or crop stover in a line along the contour.

- Establish the contours
- Arrange trash or cut grass on the contours
- Make each trash line between 0.5 and 1.0 m wide
- If the land is very steep, put pegs below the trash to anchor it
- If possible, elephant grass and suitable trees should be established along the trash line for stability.

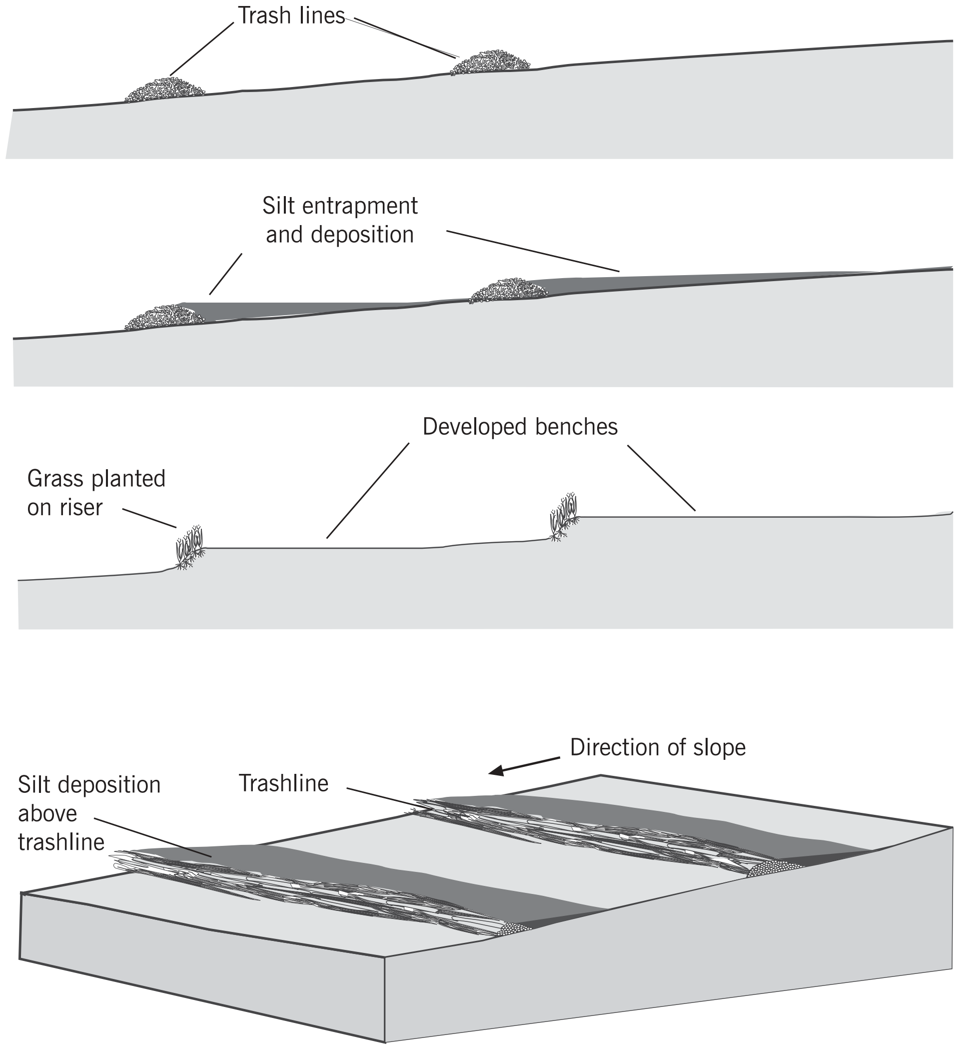


Figure 4. *Bench terraces developed from trash lines.*

Strip cropping

Strip cropping is a type of wash-stop. The land is divided into long narrow strips along the contour. Then strips of widely spaced annual crops are alternated with other crops that have good ground cover. The effect is to control runoff and to trap any soil from upslope. In semi-pastoral areas, the strip of perennial crops could be grass for grazing livestock. However, use of grasses, although effective in reducing soil loss, has three main disadvantages:

- The long and narrow plots are difficult to graze as they usually require fences
- Insect pests tend to concentrate on the borders of the crop strips
- Some grasses that have underground stolons may invade the neighbouring crops.

Strip cropping is best on permeable soils and on slopes that are not too steep, preferably those not exceeding 15%. Strip cropping alone is not adequate for slopes exceeding 15%, in which case other measures should be added. The steeper the slope the narrower the strip.

Table 1. *Width of crop strips with varying slopes*

Slope %	Width of crop strip
30–20	Tentatively 10 m or smaller if the situation demands it
20–12	About 20 m
Less than 12	About 30 m

Stone lines

A stone line is a wash-stop that is formed by arranging and heaping stones in a line along the contour. Stone lines conserve soil through:

- Trapping soil above the riser
- Slowing down the speed of runoff.

To make a stone line, a shallow and level trench about 30 cm deep is dug across the slope to anchor the stones. Big flat stones are then placed in the bottom of the trench, followed by a layer of smaller stones. The stones are arranged until the pile (called a stone riser) is high enough (approximately 0.5 m). The spacing of the stone lines depends on the steepness of the slope. A steep slope will have more and closer stone lines than a gentle one. Where stones are readily available on the farm, construction of stone lines may be the best alternative for soil conservation. Stones that fall off the riser should be replaced.

Crop rotations

This is the growing of different crops in a given place (field) in successive years. During their growth, different crops need different minerals, have different root depths and attract different diseases and pests. Crop rotation ensures the soil does not become depleted and pests do not build up. A legume crop is always included in a rotation as it adds nitrogen to the soil by means of bacteria that live in the roots and take nitrogen from the air (nitrogen fixation).

Intercropping

This is the practice of growing two or more crops in the same field at the same time. Ideally, one of the crops should provide quick ground cover. Some crops, especially perennials, take a long time to establish a good ground cover. Under such circumstances, when mulching is not practised, intercropping can provide the required ground cover while also improving soil fertility when legumes are used. Intercropping also allows for intensive land use where land holdings are small.

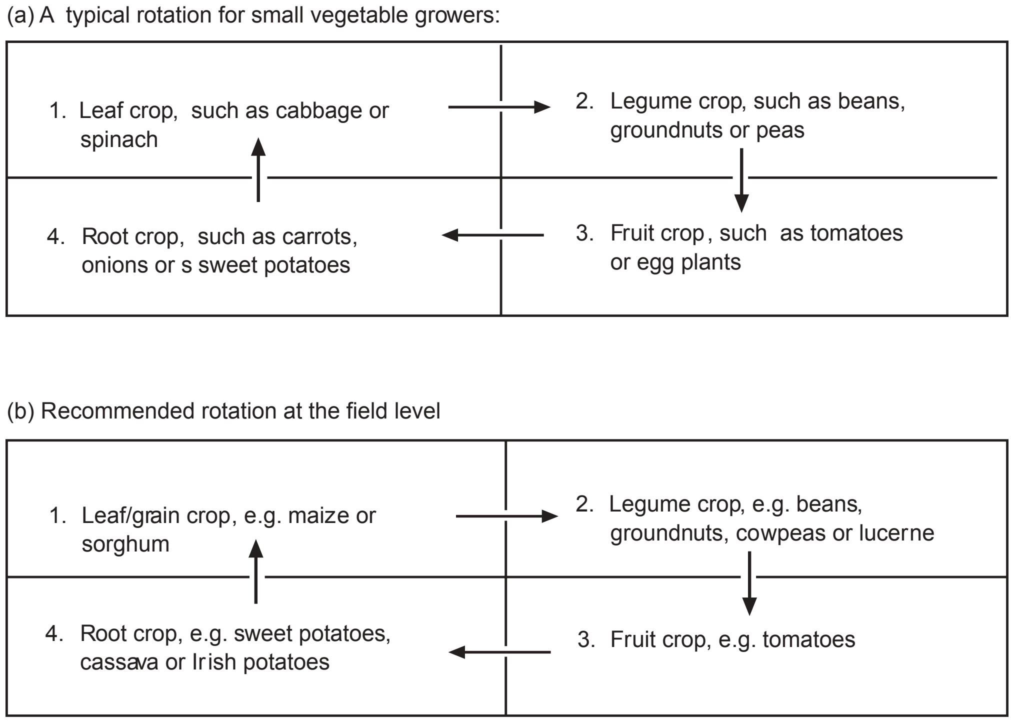


Figure 5. *Crop rotations.*

Regeneration or rehabilitation of degraded lands

Rehabilitation of degraded grazing lands can be achieved in one of the following ways, depending on the cause of the degradation:

- Closing the area to grazing, thereby allowing the natural vegetation to regenerate. To check runoff and increase infiltration, a number of furrows should be made along the contour, with a spacing of 1–3 m (1 m on completely denuded land and 3 m in areas with some grass and other vegetation). Planting of leguminous trees and bushes scattered on the grazing land is recommended.
- Closing the area and reseeding with suitable species of grasses and legumes. In this method, scratch ploughing by ox-plough or hand hoe is usually sufficient.

Windbreaks

Windbreaks are rows of trees planted across the direction of the prevailing wind.

3.3 Physical soil conservation measures

In this section we describe the structures that can be built to control the different kinds of erosion. When constructing any of these structures, it is necessary to consider a number of things, for instance, the slope of the land and the amount of water running down the slope. Physical soil conservation measures are not enough on their own to increase land productivity but should be used alongside cultural and biological measures. Keeping in mind the physical laws of water and wind flow, the choice of type of conservation measure to use is common sense, being influenced also by cultural and economic considerations.

Channel terraces (broad based or narrow based)

These are shallow channels with a wide embankment on the lower side. Broad-based terraces are normally found on large farms that use tractors for land preparation. Narrow-based terraces (also known as *fanya chini* terraces because the soil is thrown downslope) have a narrower embankment and steep sides (1:1). They can be used on slopes up to 20%. In the Uganda Soil Conservation and Agroforestry Pilot Programme (USCAPP), Mbarara, these channels have been modified by farmers to suit local conditions by planting grass on the upper and lower sides, thus stabilizing the lower embankment while filtering out and reducing the amount of silt from the upper side. Design guidelines for an area with deep soils and good infiltration rates are given in Table 2.

Table 2. *Design parameters for narrow-based channel terraces (*fanya chini*)*

Land slope (%)	Terrace spacing		Channel dimensions		Channel area
	V.I. (m)	H.I. (m)	Width (m)	Depth (m)	(m^2)
5	1.00	20	0.50	0.25	0.13
10	1.35	14	0.50	0.30	0.15
15	1.73	12	0.50	0.35	0.18
20	1.80	9	0.50	0.40	0.20

Source: Thomas (ed.) 1997.

Cut-off drains

A cut-off drain is a ditch dug across the slope of the land with one open end leading runoff into a waterway to avoid damage to the fields below. Cut-off drains are constructed on the upper part of cultivated lands and are always graded to direct water into a waterway. Water from the cut-off drain must always be directed into areas where it can be discharged safely, such as:

- A natural waterway, such as a river
- A man-made waterway
- Stony or rocky ground
- A piece of land with plenty of grass cover, or forested land.

Table 3. *Dimensions for wooden check-dams*

	Height of dam crest above gully floor (m)								
	0.3 m			0.6 m			0.9 m		
Floor gradient %	Wood and gabion	Post-brush/ stone	Stone wall with 1:1 slope	Wood and gabion	Post-brush/ stone	Stone wall with 1:1 slope	Wood and gabion	Post-brush/ stone	Stone wall with 1:1 slope
4		15.0			30.0			45.0	
6		7.5			15.0			23.0	
8		5.2			10.0			15.0	
10		4.0			7.7			12.0	
12		5.2			6.3			9.3	
14		2.7			5.3			7.8	
16		2.3			4.6				
18		1.8					6.7		7.4
20		1.7		3.7		4.5	5.4		6.7
24				3.1		3.9	4.5		6.1
28	1.4		1.7	2.7		3.4	3.9		5.4
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 1981.

Construction of a cut-off drain

Points to consider in constructing a cut-off drain are:

- Make sure that there are no big rocks or trees along the construction path.
- Decide on the width and depth of the cut-off drain according to the steepness of the slope and the amount of runoff expected to be carried.
- Decide the slant of the cut-off drain. Cut-off drains are always graded to allow water to flow down easily. As a rule of thumb, a gradient of 0.5% is suggested for good loamy soils. Steeper slopes could lead to erosion within the channel.
- The soil is dug and thrown downhill to form a ridge.
- Plant fodder grass on the ridge to make it firm and to control soil erosion through trapping some of the runoff from the slope, thereby protecting cultivated fields.

Maintenance of cut-off drains

- Remove the soil that collects in the ditch from time to time
- Plant short grass to maintain the ridge.

Check-dams

Check-dams are structures built across a gully to reduce the speed of water flow and to trap soil. They should be constructed using locally available materials. There are two common types of check-dam: wooden check-dams and stone check-dams.

Wooden check-dams

- Decide the spacing of the wooden check-dam in the gully (see Table 3 for dimensions).
- Dig a small trench across the gully floor and extend it into the gully sides to anchor the wooden materials. The width of the trench should be at least 1 m.
- Hammer two rows of wooden posts into the gully floor along the inner edges of the shallow trench, then lay branches of trees and shrubs in layers between the two rows of posts.
- Arrange some small tree branches below the constructed dam to act as an apron to check scouring below the dam.
- Tie the top of the structure with pieces of wire to hold the branches and shrubs in place.

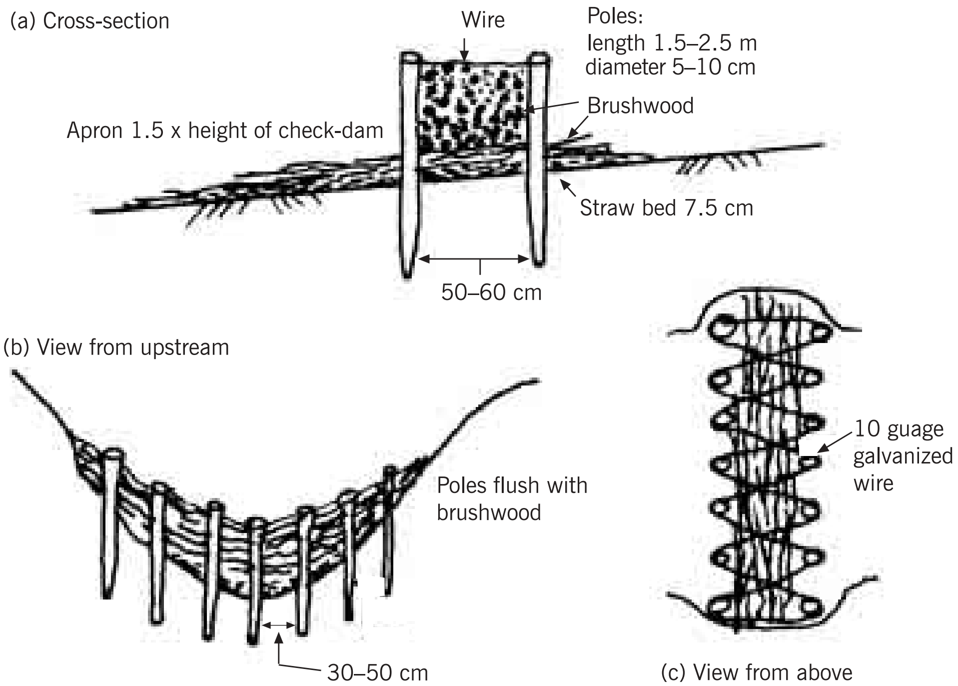
The height of a check-dam depends upon the depth of the gully, but generally 0.5 m can be considered. The spacing of check-dams will depend on the slope of the gully.

Table 4 gives details of the required dimensions of spillways for different dam widths and discharges.

Table 4. *Required dimensions for check-dam spillways*

Depth of spillway (m)	Average width of spillway (m)						
	0.6	1.2	1.8	2.4	3.0	3.6	4.8
	Discharges in m^3/s						
	0.15	0.05	0.15	0.2	0.25	0.30	0.35
	0.30	0.10	0.40	0.5	0.60	0.75	0.90
	0.45	0.20	0.70	0.9	1.20	1.40	1.50
	0.60	0.35	1.10	1.5	1.80	2.20	2.50
	0.75	0.60	2.00	2.7	3.30	3.90	4.70

Source: Wenner 1981.



Source: Thomas (ed.) 1997.

Figure 6. *A wooden check-dam.*

A stone check-dam is made of stones collected from the fields.

- Dig a trench in the gully floor extending into the sides.
- Put large stones into the trench.
- Using the stones, build a wall to the required height. The sides of the structure should be made higher than the middle.
- Arrange some stones in front of the raised wall to act as a spillway.

Note: Before opting to construct check-dams, discuss alternative productive use of a gully with the land user. A benefit-driven activity could lead to a more lasting solution to gully erosion.

Artificial waterways

Artificial waterways are wide and shallow drainage ways made down the slope. They are constructed to receive water which is discharged from cut-off drains, road culverts, mitre drains and terraces and lead it into natural watercourses (rivers) or non-erodible areas. These artificial waterways are very important in preventing uncontrolled runoff from entering farm lands, especially from new cut-off drains. If managed properly, these waterways can lead to direct improvements in productivity.

Siting of artificial waterways

Usually it is best to use the boundary between two farms as an artificial waterway. When siting the artificial waterway, the discharge point (outlet) should be selected in such a way that the risk of erosion will be as small as possible. The farmers concerned should participate in decision making and implementation to avoid future conflicts.

Maintenance of artificial waterways

The waterways should have a cover of short but thick grass to prevent erosion. They must not be used as a path for people or cattle.

3.4 Conservation in crop production

Annual crops

Annual crops are those that take one or two seasons to mature, while perennials take two or more years to mature. It is advisable that annual crops be planted on flat or gently sloping land. Since they have a very high demand for soil nutrients, they should be grown in rotation with fallow periods where the availability of land allows this. Intercropping is also encouraged to ensure proper ground cover and to obtain more than one crop from the field. Crops that are usually clean-weeded, such as maize, sunflower and cotton, should have rough seedbeds that will encourage infiltration. Appendix II gives a summary of the main requirements/recommendations for selected crops.

Perennial crops

Perennial crops are usually grown in plantations. Since the cropping period is long, it is not possible to practise crop rotation with fallow periods. Therefore, care should be taken to ensure that soil moisture and nutrients are available throughout the growing period. In order to do this, these crops should be planted on gentle slopes with erosion-control structures. Use is also made of mulching and manuring. If available, artificial fertilizers may be used to increase yields.

Conservation structures such as bench terraces, infiltration ditches, bunds and trenches must be constructed when both annual and perennial crops are grown on steep slopes. Correct farming methods must be adhered to.

Examples of some management practices for selected crops are given below.

Bananas

In Uganda, banana production is by far the most important agricultural activity, both for cash and food. Bananas are mainly grown in plantations, often on hill slopes. Falling banana production in many areas is regarded as the most critical problem facing Uganda farmers. The following management practices are recommended. Bananas should be planted in deep and fertile soils. Spacing should be close, that is, 3 x 3 m, in order to produce more but smaller bunches. However, some farmers prefer wider spacing to obtain fewer stools and therefore large bunches which are more marketable.

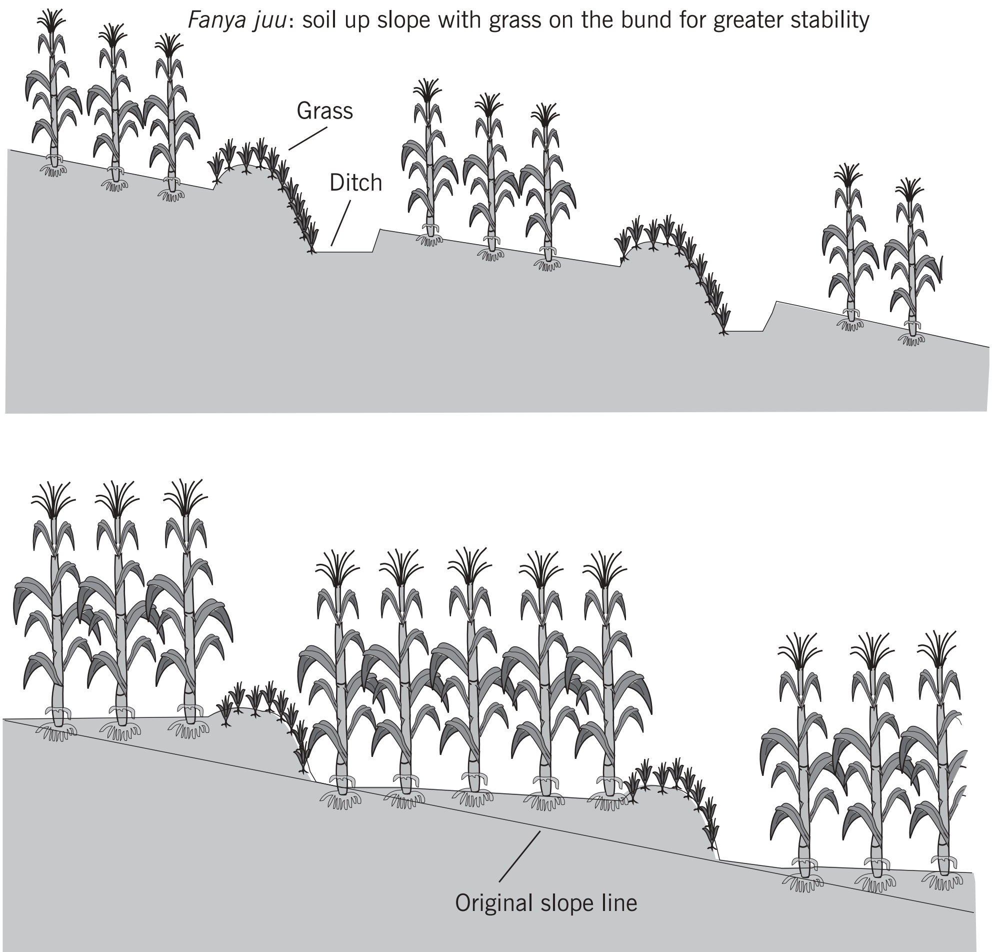


Figure 7. *Development of level benches from* fanya juu *terraces.*

Mulching is a very important agronomic practice in well-established banana plantations. Use is often made of old leaves, split stems, coffee husks, elephant grass, beanstalks and any other available organic materials.

Soil-erosion control is usually done by use of bunds, trenches and ditches, especially on sloping land where mulching is inadequate.

It is not essential to use artificial fertilizers in banana plantations, although they may increase yields. However, use of FYM usually maintains soil fertility. Intercropping and use of cover crops reduce erosion and also maintain soil fertility.

Coffee

Both Arabica and Robusta coffee are grown in plantations in Uganda and are the most important cash crop. Any reduction in coffee yields would cause great financial loss to farmers and the government. In order to improve yields in coffee plantations, the following should be practised. Planting should be done after digging planting holes three months earlier. The holes should be spaced at 2.4 x 2.4 m. Shade and windbreaks are very important for young coffee trees, using appropriate tree species such as grevillea and flemingia. Since coffee is usually planted on sloping land, soil-conservation structures must be used to reduce runoff, especially when clean-weeding is done. Mulching is very important for both young and mature coffee trees. Mulch should be applied in a thick layer (up to 10 cm deep), using any available organic matter. Every effort should be made to encourage farmers to take up clonal coffee in all suitable areas.

Terraces on cultivated land

The word 'terrace' generally describes a piece of land on which certain work has been done to change the profile of the slope. There are three types of terraces:

- *Fanya juu* terraces
- Channel terraces
- Bench terraces.

Each of these types of terrace may have many variations depending on intended use and method of formation.

Fanya juu *terraces*

A *fanya juu* terrace is a trench that is dug while throwing the soil upslope to form a riser or embankment. This embankment above the trench acts as a shallow dam to hold runoff and to trap soil and nutrients that may be contained in the runoff. The trench is often used to plant bananas or other fruit trees, especially in dry areas. In other cases, the trench may eventually be allowed to disappear as the area between the two *fanya juu* structures slowly develops into a level terrace. A suitable grass species must be planted on the embankment to stabilize the structure.

Where such *fanya juu* terraces are intended to develop into benches, then the vertical interval (V.I.) should not be more than 1.8 m. Often the farmer may chose to have wider spacing because of labour constraints, but this creates the possibility of overtopping and breaching of the structure during heavy storms. Farmers must be informed of this danger.

Important points to consider in the design of *fanya juu* terraces are:

- The capacity of the storage area formed by the embankment to hold the runoff that collects in the space between two terraces. To make this calculation first we must find out:
  - The horizontal interval (H.I.—the distance between the terraces)
  - The slope of the land
  - The infiltration capacity of the soil (rated simply as good, fair or poor)
- The height of the embankment (the riser) for the required storage. This can be worked out from Table 5, which assumes a V.I. of 1.8 m.

Table 5. *Common measurements for different designs of* fanya juu *terraces*

Land slope (%)	Terrace spacing (m)		Trench excavated to build terrace (m)		Trench area (m^2)	Shoulder bund height (upper side) to retain runoff at the following levels of infiltration (cm)		
	V.I.	H.I.	Width	Depth		Low	Medium	High
5	1.00	20	0.50	0.50	0.25	32	29	26
10	1.35	14	0.50	0.55	0.28	37	34	30
15	1.73	12	0.60	0.55	0.33	41	38	33
20	1.80	9	0.60	0.60	0.36	41	37	33

Source: Wenner 1981

In high-runoff areas, *fanya juu* terraces may be graded at 0.4–0.5% to take away excess runoff.

Bench terraces

These are level 'steps' on and across the land (on the contour). They are constructed by excavation, or they are allowed to develop gradually from a washstop, or from a *fanya juu* terrace. There are several types of bench terrace:

- Level bench terrace
- Reverse (inward sloping) bench terrace
- Forward (outward sloping) bench terrace.

Cultivation of steep land with slopes up to 55% requires the construction of either level or reverse-sloping bench terraces to control erosion. However, factors such as the depth and stability of the soils must also be taken into account in deciding whether or not to cultivate such steep land. Bench terraces are useful in dividing a long continuous slope into several shorter and gentler slopes. This reduces the speed of runoff, thus preventing erosion, increasing the rate of infiltration and improving the retention of moisture in the soil.

Excavated bench terraces are not common because of the high cost of construction. The easier alternative is to use the gradual but slower process of developing the terraces from *fanya juu* terraces or from various wash-stops (see Figure 8).

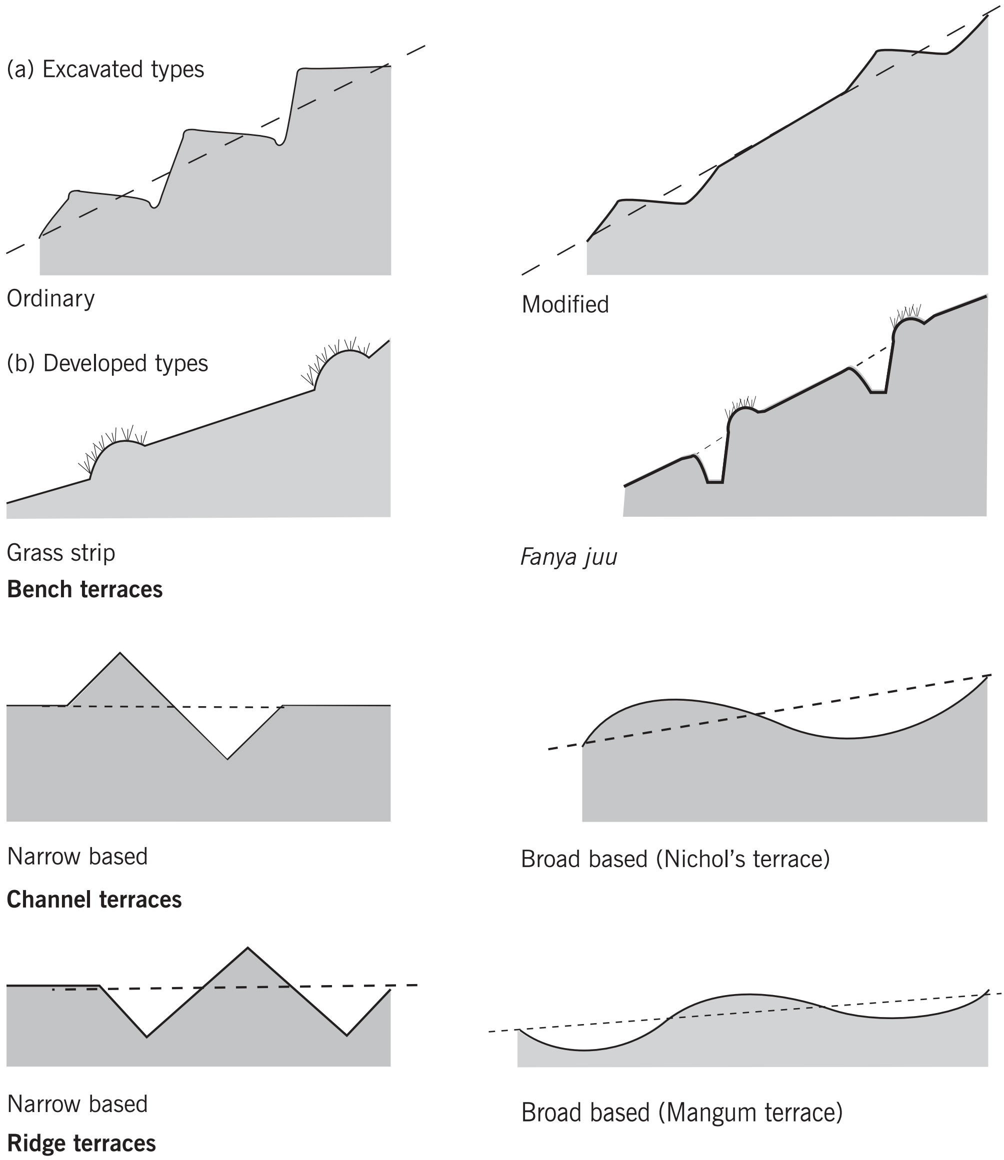


Figure 8. *Types of terraces.*

Maintenance of terraces

- The soil that is trapped in the trenches should be removed from time to time.
- Grass should be planted closely on the risers.
- For *fanya chini* terraces, suitable grass should be planted along the upper side of the ditch to trap silt transported in the runoff.

3.5 Simple survey/layout methods and equipment

There are many pieces of survey equipment that are used in laying out contours for soil conservation. These include the A-frame, the line level, the Elgon level, the water ring, the water tube level, the quickset level and the clinometer. In this manual, details will only be given for the A-frame and the line level because they are the ones commonly used in Uganda. They are fairly cheap to produce and it is simple to learn to use them. The line level is preferred to the A-frame because it gives more accurate results and is quicker to use.

The line level

The line level consists of two sticks each 1.5 m high. The sticks are graduated in 5-cm intervals, starting with zero from the top of each stick. A triangular piece of wood is attached to the bottom of each stick to prevent it from sinking into the ground. The stick should be made from good material that does not bend or break easily.

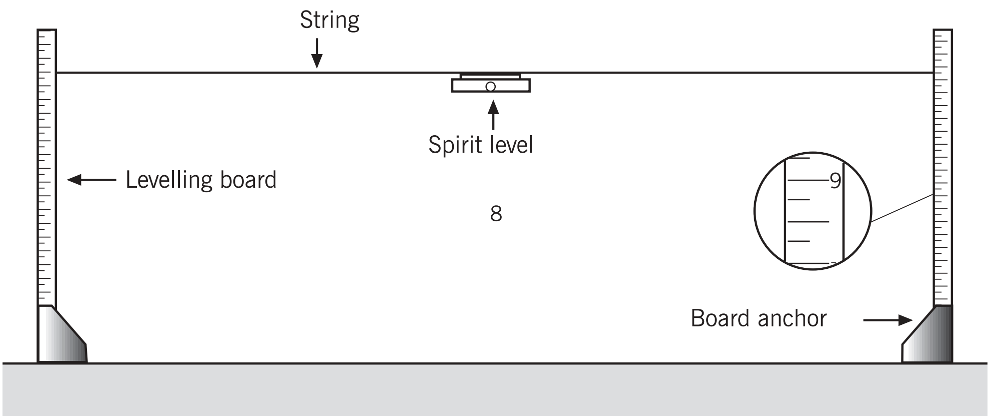


Figure 9. *A complete set of line level apparatus.*

Levelling boards

These are two pieces of graduated timber 1.5 long. The major graduations are 10 cm apart, while the minor ones are 5 cm apart. There are usually 13 major graduations. At the bottom, anchors are attached to prevent the levelling boards from sinking into soft ground.

The string

The string provides support for the spirit level. It measures 11 m (1,100 cm).

The spirit level

This is a flat instrument containing a tube of liquid with an air bubble in it. It also has hooks for suspending it on the string.

The principle behind the use of the spirit level is as follows:
The line level operates on the 'slope theory'. Slope is defined as the vertical drop, or vertical interval (V.I.), divided by the horizontal distance and expressed as a percentage (see Figure 10).

Slope = (V.I./ H.I.) x 100%.

The steeper the slope the smaller the horizontal interval.

Hence: $\text{V.I.} = \dfrac{\%\ \text{slope} + 2}{4}$ for gentle slopes, and

$\text{V.I.} = \dfrac{\%\ \text{slope} + 1}{8}$ for bench terraces on steep slopes.

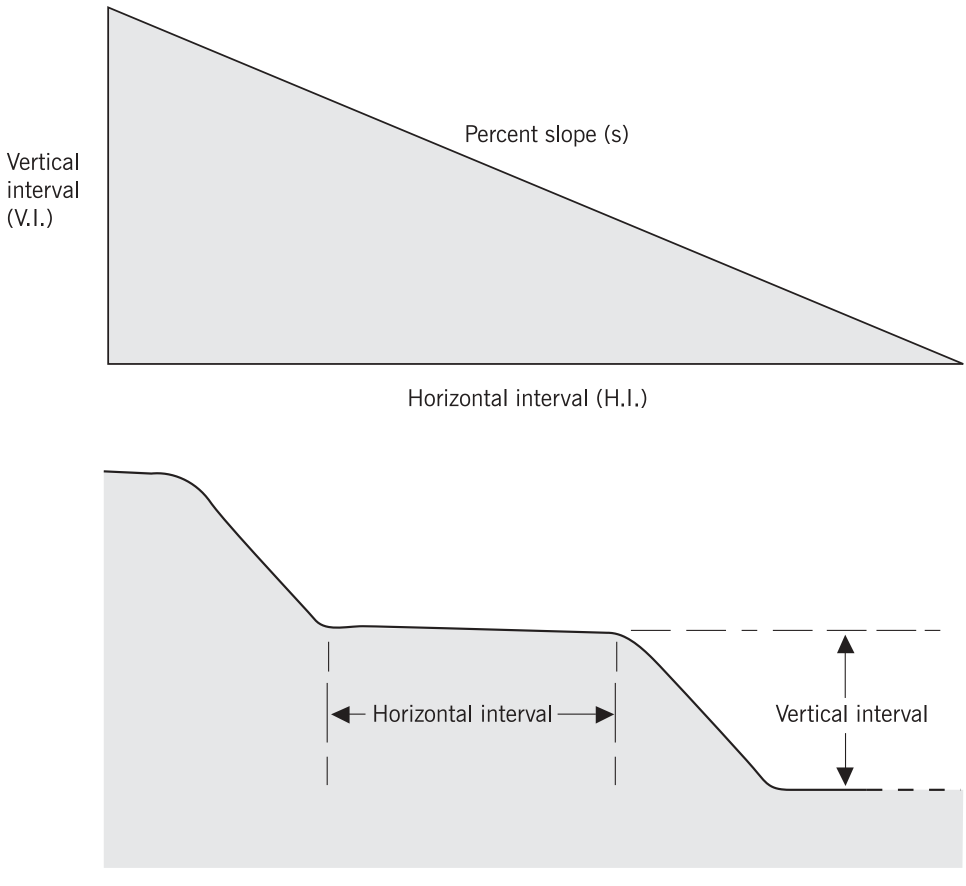


Figure 10. *The slope theory.*

Uses of the line level

- Measurement of V.I. for spacing of contours
- Determining the percentage slope
- Layout of contours.

The accuracy of the spirit level *must* always be checked before any measurements are done. This can be done by first setting up the levelling boards, string and spirit level so that the string is level and the bubble in the spirit level is in the centre. The spirit level is then removed from the string and turned round 180° so that it is facing the opposite direction. If the bubble remains in the same position, the spirit level is good. If not, the spirit level should be discarded.

Measurement of V.I.

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

Note: A smaller V.I. should be used for more erodible soils, and the maximum H.I. should not exceed 20 m. When measuring V.I., the length of the string is not defined and will therefore differ depending on the determined V.I. and slope gradient. If graded terraces are to be constructed, the V.I.s are normally set out from the end nearest the waterway or discharge point. Each V.I. point should be well marked, as the V.I. marks will be the starting point for layout of each contour. Remove the temporary marks to avoid mistakes.

It is common to use a constant V.I. (normally varying from 1.5 to 2.0 m).

- Measurements start from the upper end of the field, going downslope.
- Decide what V.I. you should use. For deep soils with good infiltration, heavily mulched soils, or those with a permanent cover crop, the V.I. could be large. A smaller V.I. should be used for shallow soils, easily erodible soils and on steep land (so that the H.I. is also small).
- The string is tied at the zero mark on the lower tied stick. Since the stick is only 1.5 m, and you have decided a 2 m V.I., the measurement must be made in two steps. The string is therefore placed at the 100-cm mark on the untied stick.
- The spirit level is placed at the mid-point of the string and the person with the tied stick moves up or down the slope, keeping the string tight, until the spirit level reads level.
- You have now measured a 100-cm (1 m) vertical interval. Make a temporary mark at the position of the tied stick.
- Repeat the exercise by placing the person with the untied stick at the temporary mark while the person with the tied stick moves further down the slope.
- The second measurement of 100 cm (1 m) will give the intended V.I. of 2 m (100 + 100 cm). Here you place a permanent mark on the tied stick.
- Continue to mark the V.I. down the slope until you reach the end of the farm.

Layout of level terraces

- To lay out level terraces, put the string at the zero mark on both sticks.

- Start from the top, at the first V.I. point pegged out, and lay the contour across the slope.
- The person with the tied stick starts from the V.I. point. The person by the spirit level directs the person with the untied stick to move up or down hill, while keeping the string tight, until the spirit reads level.
- A peg is driven into the ground against the untied stick. The process is then repeated with the tied stick being moved to the new peg.
- In case the pegs are moved or lost, their positions should be further marked by ploughing or digging along the contour.
- On reaching the end of the field, if the last point is less than 10 m, the string can be shortened to fit the distance.
- The fixed pegs should be realigned to make a smooth curve in the contour.

Layout of graded terraces and drains

Use 10-m string. Depending on the selected gradient, place the string on the untied stick as follows:

- The string placed at 5 cm on the untied stick = 0.5% (for stable soils)
- The string placed at 2.5 cm on the untied stick = 0.25% (for erodible soils).

Laying of contours proceeds in the same way as for level contours, but laying graded terraces must start from the drainage point to ensure that runoff from the channels drains into the intended drainage area.

Note: Contours should be laid smoothly across the slope to avoid sharp corners and depressions where water can break through and develop rills or gullies. Therefore, it is important to check each contour before construction, and to smoothen out the contour if necessary.

Determining the percentage slope

The percentage slope is measured to determine what type of structures and intervals (V.I.) should be used. Three people are needed to measure the percentage slope: two people holding the boards, and one person reading from the spirit level.

Procedure

- Select a place that is representative of the field and align 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.
- 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.
- Read from the graduation mark on the untied board when the string is level.

To make the calculation to determine the percentage slope, all figures must be calculated in metres. The centimetre mark that is read from the board must therefore be converted into metres: 10 cm = 0.1 m (example: 50 cm read from the board = 0.5 m).

Gentle slopes up to 15%

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

$$\text{Slope \%} = \frac{\text{(difference in height read from the board in cm)} \times 100}{\text{Length of string (m)}}$$

Example: 10-m string (and 90-cm difference as read on the board):

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

Slopes of 16%–30%

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

Example: 5-m string:

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

Steep slopes of 31–60%

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

Example: 2.5-m string:

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

Additional examples

Example 1: In the example below, 0.8 m (80 cm) is read from the untied board using a 10 m string. The percentage slope will be as follows:

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

Example 2: Below is an example from a steeper slope. Eighty centimetres is read from the untied board, using a 5-m string. The percentage slope will be:

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

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

The A-frame

The A-frame is a simple instrument which looks like the letter 'A'. It is made of 3 poles, a string and a small stone. It can therefore be made in any village. The A-frame is appropriate for farmers pegging their own contours in small fields when a spirit level is not available. If a spirit level is available, the line level is probably to be preferred.

Note: The A-frame cannot be used in measuring the percentage slope or the vertical interval.

Construction and calibration of the A-frame

Materials required

- 3 poles each 2.5 m long
- 3 2-inch nails and a strong piece of string
- 4 m of strong string
- 1 small stone
- 2 pegs 50 cm long.

Method of construction

- Cross 2 poles at the top, tie securely and nail them together.
- Tie the third pole across the two poles to make an 'A', and nail them together. The crossbar should be tied at least 50 cm from the ground.
- Tie the string at the top of the 'A' and let it hang down to below the crossbar.
- Tie the small stone on the string so that the stone hangs just below the crossbar, as in Figure 11.

Calibration of the A-frame

Position the A-frame upright on a flat area and drive a peg into the ground on the outer side of each of the two legs. Make a light mark with charcoal or a light scratch to show where the string crosses the crossbar (mark 'a'). Now reverse the position of the legs, and ensure they touch the bar. Again mark the point where the string crosses the crossbar (mark 'b'). (See Figure 11.) Measure the halfway point between the two marks 'a' and 'b' and make a deep permanent mark at this halfway point. It will indicate the reference point for the A-frame.

Pegging a level contour with the A-frame

- Put the first peg in the ground on the line that is to be pegged and set up the A-frame with one foot at this point and the other along the approximate level contour line.
- The person by the string directs the one by the leading foot (i.e. the foot which is not next to a peg) to move up or down hill until the A-frame reads level, i.e. the string passes the crossbar exactly at the calibration mark. A peg is hammered into the ground by the leading foot.

- This process is repeated with the first foot being moved to the new peg and the leading foot moved further along the line until there is a line of pegs on the same level contour, every 3 m or so.

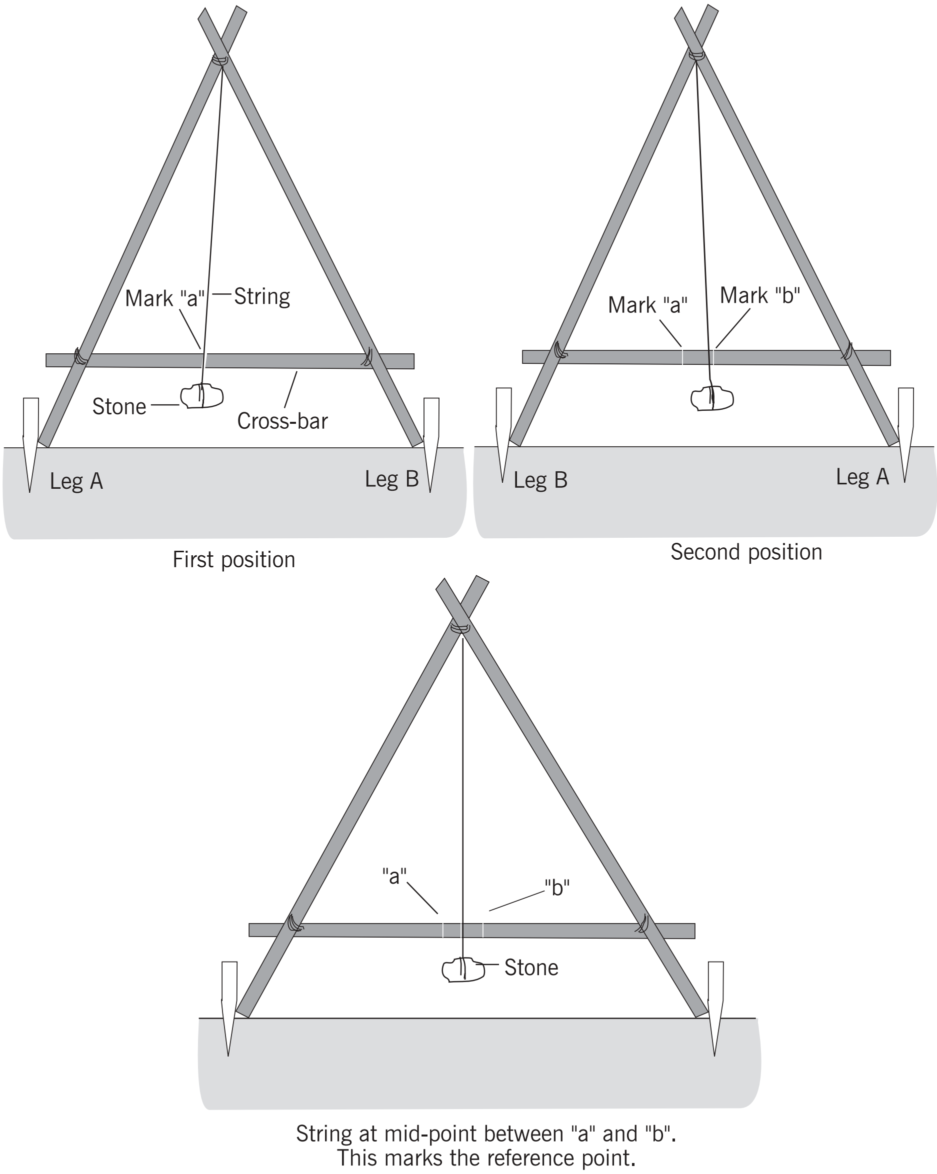


Figure 11. *Calibrating the A-frame.*

4. Fertility improvement and management

4.1 Introduction

A decline in soil fertility is the main cause of low agricultural production in most areas of Uganda. This problem could be solved by intensive use of artificial fertilizers. However, this is not always a practical solution because most small-scale farmers do not have access to these such fertilizers, or they are too expensive for the majority of them to be able to purchase.

4.2 Causes of decline in soil fertility

Decline in soil fertility is mainly caused by poor farming practices, such as:

- Continuous cultivation of the same piece of land without adequate rest (fallowing), or without effective replenishment of the soil organic matter and nutrients.
- Burning, which leads to the destruction of soil organic matter and kills some of the important soil micro-organisms that are necessary for decomposition of litter and other organic matter into humus. Burning also causes loss of soil nitrogen and sulphur to the atmosphere.
- Abandonment of good traditional soil fertility maintenance practices, such as fallowing, proper utilization of animal manure and intercropping with legumes.

These practices in turn lead to poor soil fertility by the following processes.

Soil erosion

This causes loss of soil nutrients, humus particles (organic matter) and mineral particles from the topsoil.

Leaching

This is the movement of soil nutrients into the deeper layers of the soil profile through percolation of rainwater. Leaching is a natural process, but in most ecosystems the coexistence of many plant species minimizes the loss of nutrients. However, in farming, and particularly in continuous monocropping, significant amounts of nutrients are leached beyond the root zone and thus lost from the system. Such loss of nutrients is common in humid areas of Uganda, and in other areas where soils have high infiltration rates. Leaching mainly causes loss of soluble nutrients such as nitrates and bases such as calcium, potassium and magnesium, and it often leads to increased soil acidity.

Soil mining

This refers to the continuous removal of soil nutrients during crop harvest and the removal of crop residues for burning or for livestock feed.

4.3 Soil fertility management

Maintenance of soil fertility requires a combination of measures that can improve the soil both chemically and physically. The following are good-soil management measures which farmers should adopt in order to improve soil fertility and increase crop production.

Control of soil erosion

Soil lost from fields, with nutrients and organic matter, is often deposited where it is not useful for production. Good land-management practices will help to retain soil nutrients in cultivated land for crop production.

Inorganic fertilizers

If nutrients are not available, or cannot be adequately supplied by application of organic matter, inorganic fertilizers must be applied. Currently, there is only minimal use of inorganic fertilizers in most parts of the country. The high cost of using imported inorganic fertilizers can be avoided through use of locally available rock phosphate.

Supply of organic matter to the soil

Organic matter must be added regularly to provide necessary nutrients and to improve soil structure and increase water-retention capacity. Addition of organic matter is essential for land productivity as 98% of the plant's requirements of nitrogen, 85–95% of the requirements for sulphur, and 20–50% of readily available phosphorus is contained in organic matter.

The main types of organic matter that can be used are described below.

Mulch

Mulch releases necessary nutrients upon decomposition, reduces soil erosion that is caused by rain splash and runoff, reduces the maximum daily soil temperature, thus preventing loss of nitrogen through volatilization, and prevents loss of soil moisture. Growing grass and shrubs on conservation structures helps increase the supply of mulching materials.

Crop residues and weeds

These should be incorporated into the soil rather than being burnt during land preparation. In areas where crop residues are a main source of fodder for livestock during the dry season, farmers should be encouraged to transfer FYM to cultivated land.

Compost and FYM

Compost is the finished product resulting from a decomposed mixture of organic wastes and is valuable for use in soil improvement. Compost helps in the creation of good conditions for soil organisms, including supply of organic matter, improving the soil's moisture-holding capacity, and preventing conditions which lead to the creation of extreme alkalinity or acidity.

- Integration of livestock in the farming system in order to provide enclosure (kraal or *boma*) manure which can be applied to improve fertility.
- Incorporating multipurpose trees in fields in the farming system. The deep roots take up nutrients from the lower soil profile and bring them to the topsoil through leaf fall. Leguminous shrubs and trees also help to fix nitrogen in the soil.
- Integration of legumes in the crop rotation cycle, either intercropped or as cover crops. Many leguminous plants fix atmospheric nitrogen which is then incorporated into the soil.
- Proper tillage methods (see Section 3.2, above).
- Timely planting.

4.4 Farmyard manure

Farmyard manure (FYM) is obtained from animal droppings and bedding which should be heaped in a safe place and allowed to decay properly before being applied to fields. It is easier to manage animal droppings and manure if animals are kept in confined places during the night, or housed in the case of zero-grazing. If the floor of the structure where animals are housed is made of concrete, provision should be made for directing urine to a safe place for storage. Collected urine can be applied directly on fields or used for making compost.

4.5 Making and use of compost

Farmers can produce compost by constructing pits or making heaps near their homes so that kitchen waste, some crop residues and animal droppings and bedding can be piled in them. The process of making compost generates heat, which destroys the germinating power of weed seeds that are present in the composting material. Therefore, when compost is applied to a field, it does not cause excessive weed growth as is sometimes the case with ordinary manure. On many soils, good yields can be obtained by simply applying compost without using large amounts of inorganic fertilizers.

Compost and FYM are important for improving land productivity because they can supply most of the minerals necessary for healthy plant growth at a lower cost than inorganic fertilizers. Compost and FYM also hold up to 6 times their own weight of water, thus improving the water-holding capacity of the soil. They help to loosen clay soils and to make sandy soils less porous because of their light texture, thus improving the soil's structure. The beneficial effects of adding compost to the soil are more long lasting than in the case of inorganic fertilizers.

Materials needed for making compost

- Vegetative materials from the farm
- Good topsoil
- FYM
- Ash from kitchen stoves
- Some water (about 100 litres)
- A long sharp-pointed stick.

Steps in making compost

- Select a place that is cool and shady and with well-drained soil. Mark out a section 1.5 m wide. The length will depend on the available vegetative materials. It must be possible to work on the compost without stepping on it.
- Loosen the ground where the compost pile will be. The materials need close contact with the loose soil at the bottom. It is best to make a shallow trench about 30 cm deep. In dry areas, the trench or pit can be as deep as 1 m. The topsoil obtained will be used in the compost. Therefore put it on one side beside the trench.
- Put down the bottom layer, which should be rough vegetation such as maize stalks or hedge cuttings. This layer should be about 30 cm thick. Long pieces should be chopped up.
- Sprinkle some water on this layer, thereafter on each new layer as it is added.
- The second layer should be manure, about 10 cm thick.
- Next, sprinkle a thin layer of topsoil or old compost or, if available, slurry from a biogas plant.
- The next layer should be made up of green vegetation, about 15–20 cm thick. Use green weeds, grass, hedge cuttings or kitchen waste.
- Sprinkle ash or charcoal dust on top of the green vegetation.
- Repeat the whole process again, starting with dry vegetation, then manure or old compost, topsoil, green vegetation, ash or soil, and watering every layer as you build up the pile.
- When the pile is about 1.5 m high, apply a final layer of topsoil to about 10-cm thickness. Cover the whole pile with dry vegetation to prevent evaporation.

- Take a sharp-pointed stick and drive it into the pile at an angle. This stick assists in showing the progress in the decomposition process. Within 2–3 days decomposition will have started in the pile. The stick, when removed, should feel warm. The stick should be left in the pile and regularly removed and felt for warmth. Depending on the weather conditions, the pile should be watered every 3 days. This is not necessary when it is raining.
- After 3 weeks, turn the pile, and then again after another 3 weeks, all the time checking if decomposition is continuing. If the stick feels cool or when it has developed a white powdery substance, then decomposition has stopped. Turning over the heap helps mix the materials again to restart decomposition.
- Keep checking the warmth of the compost pile at regular intervals by feeling the stick. The compost is ready when the stick finally feels cool. This occurs after approximately 3 months.
- If the compost is not to be used immediately, put on a final layer of topsoil about 10 cm thick and cover the whole pile again with dry vegetation to prevent evaporation until the compost is needed.

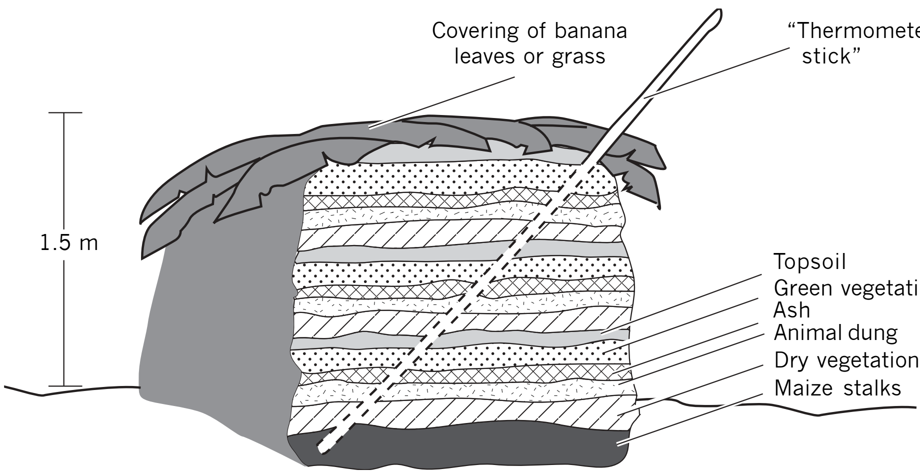


Figure 12. *Different layers in a compost heap or pit.*

Compost from household organic waste or crop residues

Small regular quantities of compost can be made from household organic waste or crop residues such as banana peelings, bean trash, groundnut trash, coffee husks, chicken and goat droppings, etc.

- Dig a pit 1.5 m long x 0.5 m wide and 0.5 m deep, in a cool shady place.
- Fill the pit with the organic material.
- Sprinkle the top with wood ash or a mixture of wood ash and dung, if available.

- If animal urine is available, dilute with water 1:4 and sprinkle over the heap.
- Cover the heap with topsoil to a thickness of about 10 cm followed by dry vegetation to avoid evaporation.
- Water the heap at frequent intervals.
- Drive a pointed stick at an angle into the heap and regularly remove it to feel for warmth. This should be continued until the stick feels cool when removed.
- Dig a new pit.
- Transfer the contents of the first pit into the new pit. Cover as above and water as required. After 2–3 weeks the compost should be ready for use. Test with the stick as above.
- Fill the first pit with fresh organic material and repeat the procedure.

Application recommendations

Farmers can improve soil fertility by composting. The nutritive value of compost depends upon the amount and nutrient content, the age of the compost and the method of storage. Application rates should not exceed crop requirements. It is often recommended that 25 tonnes per hectare be applied on loams and 38 t/ha on sandy loams. In the case of row crops, these amounts could be reduced significantly by restricting the application of the compost to the planting row, or to each pit with trees and bushy plants.

4.6 Improvement of biological activity

A high level of biological activity in cultivated land can be sustained by:

- Continuous supply of organic matter to the soil.
- Turning over crop and plant residues during tillage and weeding.
- Avoiding unnecessary bush fires or burning of crop residues. Fire kills soil organisms and destroys organic matter that is necessary for the survival of the micro-organisms. Healthy soils contain many macro- and micro-organisms.

Functions of soil organisms are:

- Breaking down organic matter to release nutrients locked in the plant materials
- Some micro-organisms fix atmospheric nitrogen
- Breaking down rock particles which hastens the mineralization process
- Holding soil particles together to create aggregates, which in turn influence soil structure and water infiltration.

Macro-organisms such as termites improve soil structure by burrowing openings in the soil which improve soil aeration and moisture infiltration. Earthworms also help in mixing up the soil and this contributes to aggregating soil particles that hold nutrients, thus reducing leaching.

4.7 Role of leguminous plants (shrubs and trees) and leguminous cover crops

Leguminous trees and shrubs play a vital role in improving soil fertility. They help to retrieve soil nutrients that are lost through leaching, and fix atmospheric nitrogen, which becomes available for crops upon breakdown.

Leguminous cover crops are close growing and mostly short crops planted between tree crops, or during breaks in the annual cropping cycle, to protect soil from erosion. Leguminous cover crops also add nitrogen to soil. Most leguminous cover crops can be used as fodder. Some common leguminous cover crops are:

- Sunn hemp (*Crotalaria juncea*)
- Tropical kudzu (*Pueraria phaseoloides*)
- Centrosema (*Centrosema pubescens*)
- *Desmodium* spp.
- Velvet bean (*Mucuna capitata*)
- Cowpeas (*Vigna sinensis*)
- Lablab bean (*Lablab purpureus*)
- Stylo (*Stylosanthes guinanensis*).

Pigeon peas (*Cajanus cajan*) are also a useful leguminous crop. Sweet potatoes (*Ipomoea batatas*) and pumpkins can also be used as cover crops. Some aggressive legumes such as tropical kudzu, hairy stylo and desmodium should not be used in banana plantations.

4.8 Green manuring

This is the ploughing in of green plant material to improve the soil. Green manure is an affordable and convenient source of organic matter to replenish plant nutrients, improve soil structure and minimize runoff and soil erosion. Plants that can be used to provide green manure include cover crops such as velvet beans which can be ploughed in at the end of the growing season. Another good plant is sunn hemp.

4.9 Fallowing

This refers to the practice of leaving land uncultivated for a period of time to allow it to 'rest'. It also includes improved fallowing where fallow land is planted with leguminous shrubs to speed up the rate of soil recovery. Fallowing is practised to:

- Restore the soil crumb structure
- Increase the soil organic matter content
- Help ensure recycling of soil nutrients from the subsoil.

4.10 Integrated fertilizer use

Proper use of inorganic fertilizer can replace most of the nutrients lost from the soil and also promote faster development of the crop cover, which protects the soil from water and wind erosion. Inorganic fertilizers can add nutrients that may not be supplied by organic manures. The kinds and amounts of fertilizer to be used depend upon the different types of soils and crops. Nitrogen, phosphorus and potassium (NPK) are the main elements needed. Since fertilizers are expensive, they must be applied properly with minimum wastage. For best results, use fertilizers in conjunction with compost, FYM and green manure, which ever is available.

Waste can be avoided if fertilizers are applied in accordance with the specific nutrient requirements determined through soil sampling. The Soils and Soil Fertility Management Programme (SSFMP) at Kawanda Agricultural Research Institute (KARI) offers a diagnostic soil service to farmers throughout Uganda. Farmers are advised to have their soils sampled and tested so that recommendations on fertilizers and other advice can be given appropriately.

4.11 Soil sampling

Divide the sample area into equal units within which the soil and land appear to be uniform. Thus:

- Within a unit the soil colour should be the same
- Sandy and clay soils should be sampled separately
- Higher and lower parts of a slope should be sampled as separate units
- Fields with different previous treatments or cropping history should be sampled separately
- If a field has an area of about 1 ha (or 2.5 acres), then about 10 uniform units should be sampled separately
- If the area is large (many hectares), then larger sampling units must be used to minimize the number of samples (a farm plan would help indicate logical units to sample separately).

Make a diagram of the field showing the position of each sampling units.

- A diagram of the arrangement of units within the total area should be made (indicating approximate length), and each unit should be numbered.
- If the total area is large, divide it into fields and make a diagram indicating numbered fields and sampling units (you can use letters for fields and numbers for the units).
- Indicate the direction of the slope of the field on the sketch.

Equipment and materials

- Flat hoe, spade or auger.
- Clean plastic basin/pail or clean plastic sheeting (about 0.5 m).
- Labels (cut a plain sheet of paper into 8 pieces) and a pencil.

- Plastic bags big enough for 1 kg of sugar.
- String for tying sample bags.

Soil sampling procedure

- Mark 20 cm (from the bottom) on the hoe or the implement you will be using to take soil samples.
- Within each unit, collect 5 sub-samples (dig into the soil up to the 20-cm mark) in a zigzag manner and in such a way that the 5 samples represent the whole unit. If, after taking 5 samples you have not covered the unit, take more samples.
- When sampling, avoid areas that are clearly not representative of the unit, e.g. do not sample very close to anthills or tree trunks.
- Put the samples into the basin/pail (or plastic sheeting), break up clods and mix the soil thoroughly (this is the composite sample).
- Using a small cup, take sub-samples from the composite sample and put them into a plastic bag (the total sample should be about 1 kg).
- Using a pencil, write the field and unit numbers on a label and put it inside the bag. Leave the bag in the unit until you finish sampling all the units.
- Move to another unit and repeat the above steps.
- When all the units have been sampled, collect the samples following the plan in your diagram and checking that each sample has a label matching the diagram.

Write the following information on a separate sheet of paper and send it with the soil samples:

- Name of the farmer; location of the farm in Uganda (village, Sub-County, County, District).
- Position of the sampled farm (e.g. hilltop, upper slope, lower slope, or valley). Include this information on the field diagram.
- History of land use over the previous 5 years: crops grown, and any soil amendments applied, for example, was manure or fertilizer applied? If so when? Were crop residues removed after each crop? If not, what happened to the residue? Indicate the crops for which recommendations are required (that is, the crops that the farmer intends to plant in the sampled area).

Despatching the samples

- Samples should be sent to Kawanda for analysis soon after sampling. This should be 2–3 months before the beginning of the rains.
- If for some reason you cannot send the samples immediately, keep the bags open but avoid contamination (keep away from fertilizers, smoke, dust, ashes).
- If the plastic bags used are not strong enough, double them up for transportation.

5. Water management

5.1 Introduction

Water is a critical resource for increased food production. Good crop growth depends not only on soil fertility but also on adequate moisture. Although most parts of Uganda receive sufficient rainfall, much of this rainfall is lost as runoff. Water conservation and management are therefore necessary for sustainable agricultural production. There is a need for better water conservation measures because of the following problems:

- Rainfall (precipitation) tends to vary from year to year, and even from season to season
- In drier areas much of the rainfall is concentrated into a few heavy storms, and this leads to wastage of water in the form of runoff
- Also in dry areas rainfall is concentrated in a few months with the rest of the year experiencing long dry spells
- High rates of evaporation and transpiration in dry areas cause soils to dry out very soon after the rain has fallen
- Poor land management promotes excessive runoff and reduced infiltration of rainwater into the soil.

5.2 Strategies for improving soil moisture availability and use

The aim is to promote efficient use of rainfall by adopting the following strategies:

- Maximizing the intake of moisture into the soil (infiltration and retention) to make it available to crops
- Collection and storage of excess runoff for irrigation, livestock and human consumption.

The following are some of the measures which farmers should adopt in order to maximize the infiltration of moisture into the soil:

- Planting cover crops to provide ground cover and to slow down runoff; strip cropping to improve infiltration and reduce soil erosion; mulching to reduce evaporation, reduce raindrop impact and add organic matter; and leaving crop residues in the field to reduce soil erosion and add organic matter
- Proper tillage such as sub-soiling to increase infiltration and to crack hardpan
- Contour cultivation to reduce runoff and increase infiltration
- Construction of water-retention structures such as terraces (*fanya juu* and *fanya chini*), ridging and bunding to reduce soil erosion, check runoff speed and promote infiltration
- Reduction of evaporation losses by mulching and by planting hedges and shelterbelts to reduce wind speeds and therefore to lower the rate of evaporation
- Weeding to reduce soil-moisture loss and to lessen competition for moisture
- Optimizing use of soil moisture by intercropping
- Fallowing, where possible, to enable the soil to regain structure, to build up plant nutrients and to improve moisture-holding capacity
- Dry seeding (sowing seeds before the onset of the rains) to enable optimal utilization of early rains by the plants
- In dry areas, sparse seeding or reduced plant population to optimize moisture use by giving each plant room to spread its roots to collect moisture
- Constructing physical water-retention structures
- Establishment of windbreaks and shelterbelts to reduce moisture loss through evaporation.

5.3 Measures for conserving rainfall runoff

Water harvesting is any form of *in situ* or external rain-water collection and concentration from natural and man-made catchments (surfaces) for productive purposes by a single household or group of households. Water harvesting can be for crop production, for household and livestock use or for range development.

Water harvesting for crop production

Normal *fanya juu*, described earlier, and enlarged *fanya juu* with a deep trench to collect and store water.

Retention ditches or contour bunds (*fanya chini*)

These are commonly used to conserve moisture in banana fields. A retention ditch is a small trench dug across the slope, and having a rectangular cross-section, a level bottom and closed ends. Contour bunds are earth or stone bunds built across the slope (along the contour). The main purpose is to collect, hold and store runoff from external catchments (sources).

The bunds should be constructed in series down the slope, 10–20 m apart.

They should be 40–60 cm high and twice as wide at the base. The bunds should be compacted and stabilized with grass. Cross ties should be constructed to prevent water accumulating in lower places. To avoid overtopping of bunds, or waterlogging of the crops, the ends of bunds should be left open, or suitable spillways provided to remove excess water. The spillways should be constructed with stones and be 10 cm above ground level on the upper side. There should be a stone apron on the lower side of the spillway to prevent scouring.

Bigger bunds should be constructed where there is plenty of runoff and where the soils have low infiltration capacity such as clay soils and shallow soils. Contour bunds are very useful in arid lands for production of crops such as sorghum, millet, cowpeas, green grams and pigeon peas.

The first retention ditch is dug at the top of the cultivated fields. The subsequent ones are dug below the first one, sometimes below several terraces. The sizes and numbers of retention ditches on the slope will depend on the amount of runoff and the length of the slope. Steps to be taken when constructing retention ditches are:

- Decide the length and size of the ditch
- Mark the ground with pegs along the contour
- Dig out soil and throw it downhill to form a ridge (*fanya chini*)
- Plant grass on the ridges and on the upper edges to stabilize the strip.

Table 6. *Retention-ditch dimensions for different situations*

A. Ditches spaced at 20 m

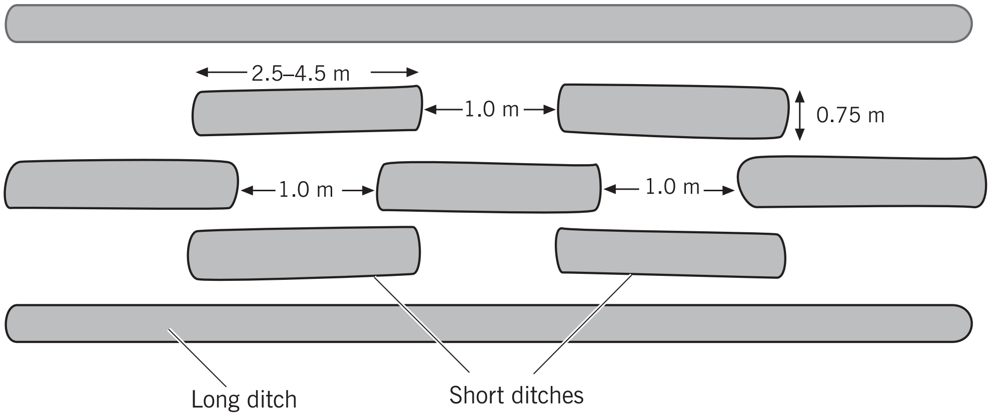
Infiltration rate in ditch	Cross-section area of ditch (m^2)	Otto width of ditch (m)	Depth	Top width (m^2)
Fast (20 mm/h)	0.56	0.50	0.54	1.58
Medium (10 mm/h)	0.62	0.50	0.54	1.66
Slow (5 mm/h)	0.65	0.50	0.60	1.70

B. Ditches spaced at 10 m

Infiltration rate in ditch	Cross-section area of ditch (m^2)	Otto width of ditch (m)	Depth	Top width (m^2)
Fast (20 mm/h)	0.28	0.50	0.34	1.18
Medium (10 mm/h)	0.31	0.50	0.36	1.22
Slow (5 mm/h)	0.33	0.50	0.38	1.29

Source: Thomas (ed.) 1997.

To reduce the cost of retention ditches, they can be constructed in the form of a discontinuous series of small ditches arranged in a staggered pattern, as shown in Figure 13.



Note: The distance to be allowed between the top ditch and the first set of discontinuous ditches is dependent on the slope of the land

Figure 13. *Retention ditches arranged in a staggered pattern.*

Maintenance of retention ditches

- Removing the soil that accumulates in the ditches from time to time.
- Repairing the embankments when they break.

Ridging and tied ridging

Ridges and tied ridges are mounds of soil constructed across the slope at predetermined intervals to trap runoff, increase surface storage and improve water infiltration in cultivated land. Ridging can also help reduce the rate of soil loss and runoff on permeable and well-aggregated soils.

- Ridging should be done on slopes up to about 3%. The ridges can be spaced 1.0–2.5 m apart and built with hand hoes or an ox plough.
- The ridge should be constructed as near to the contour as possible to minimize the risk of water running to the lowest point and breaking through.
- To ensure that ridging is done parallel to the contour, first construct a master ridge with a line level or A-frame. Subsequent ridges should run parallel to the master ridge or contour bund.
- Make tie bunds to promote uniform infiltration and reduce the risk of erosion. Ties should be slightly lower than the ridges and be spaced 1.5–2.0 m apart.

Micro-catchments

Micro-catchments are simple and cheap structures constructed to collect and hold water on planting sites. Common types of micro-catchments are:

- Semi-circular micro-catchments
- Triangular (or V-shaped) micro-catchments.

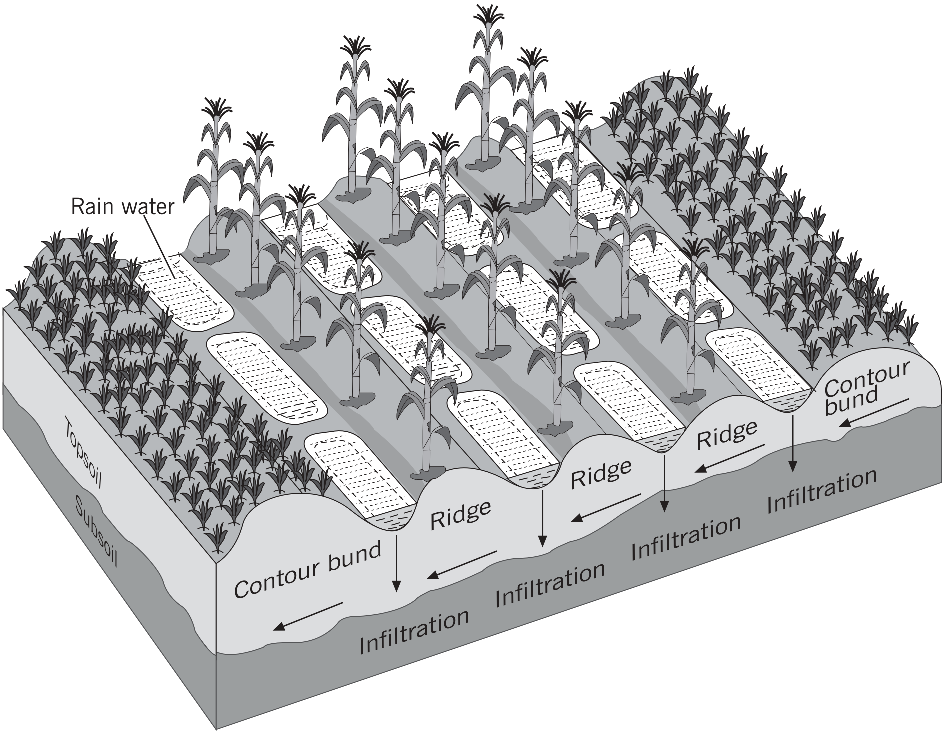


Figure 14. *Tied ridges.*

Micro-catchments are best constructed in sandy loam soil that is fairly deep to store enough water underground for plant growth during the dry season. Note that sandy soils are too permeable to allow adequate water collection. Heavy clays, on the other hand, do not allow soaking and infiltration of water into the soil; all the runoff will therefore collect at the lower end of the micro-catchment and drown young plants.

Semi-circular micro-catchments

Semi-circular micro-catchments are half-moon-shaped structures made around an existing tree or tree seedlings or leguminous ground-cover crops.

Design

Size and shape depend on intended use (large for trees, medium for crops, small for grass), soil type (small in clayish soils, medium in sandy loams, large in sandy soils), and slope of the site (small on steep slopes, large on gentle slopes). The structures should be arranged in many lines along contours.

Construction

Use 2 pieces of wood or a line level. Tie a piece of string 6.5 m long to the line levels or pieces of wood. The string should be knotted at mid-point (3.25 m). Locate the tips of the semi-circle by using a line level (or 2 pieces of wood with the strings attached and the spirit level placed at the midpoint). Start from the highest point and work downhill.

Place one line level or the wood at the point (A), and let the other person hold the other line level, or wood, and move across the slope and pull the string tight. The person who pulls the string tight moves up and down the slope until the bubble of the spirit level is at the centre. At that point, the tip of the semi-circular bund is marked (B). Fix pegs or put stones to mark these spots. Use the mid-point, 3.25 m, at the knot, and draw a semi-circle from A to B. Construct the bund using soil scraped from the area inside the semi-circle to a depth of about 10 cm. Compact the bund to prevent it from collapsing and dig a pit near the lower inner end of the structure and fill it with good soil. This is where a tree seedling or grass can be planted.

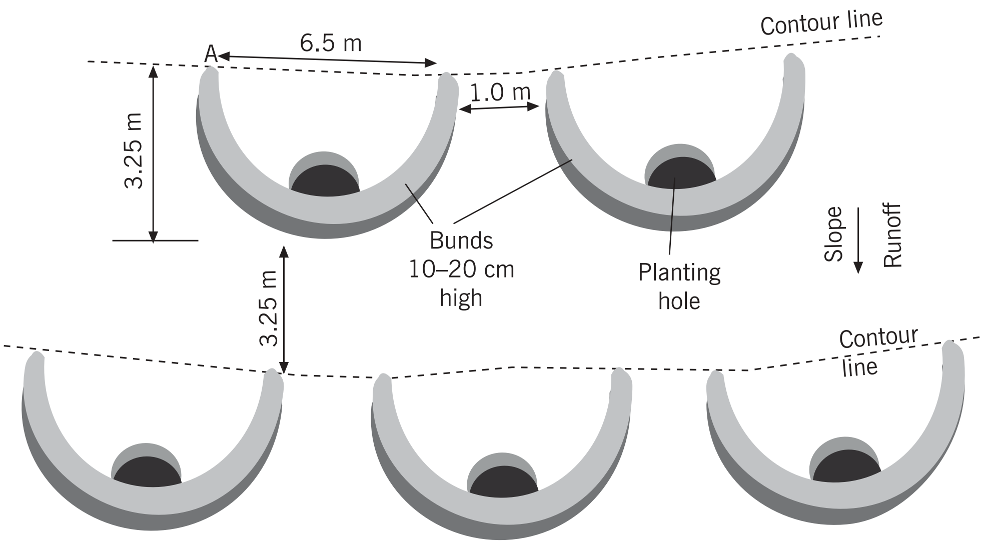


Figure 15. *Semi-circular micro-catchments*.

Triangular micro-catchments

These are V-shaped structures that are constructed across the slope to trap water for growth of plants.

Design

Spacing and size of triangular micro-catchments depend on the amount of rainfall (wider spacing for high-rainfall areas, closer spacing for low-rainfall conditions). The size of the triangular micro-catchment depends on annual rainfall conditions.

Table 7. *Annual rainfall vs. required area for micro-catchments*

Size/catchment area (m^2)	Annual rainfall (mm)
10	600
25	400
160	200

Source: Rocheleau, Weber and Field-Juma 1988.

Equipment required

- Line level (or 2 pieces of wood each 1.5 m long with notches at the same height).
- Spirit level.
- A piece of strong string 14.5 m long, knotted in the middle where the line level will be hung.
- A piece of string 20 m long, also knotted at the mid point.

Layout

Start measuring at the highest point of the land and work downhill. Determine the tips of the structure. It is important to ensure that the tips are at the same level. Tie the 14.5-m-long string on line levels or on notches of the 2 pieces of wood. The string should now be 14 m between the line levels. Mark point A and position one line level at that point. Let another person pull the other line level across the slope until it is tight.

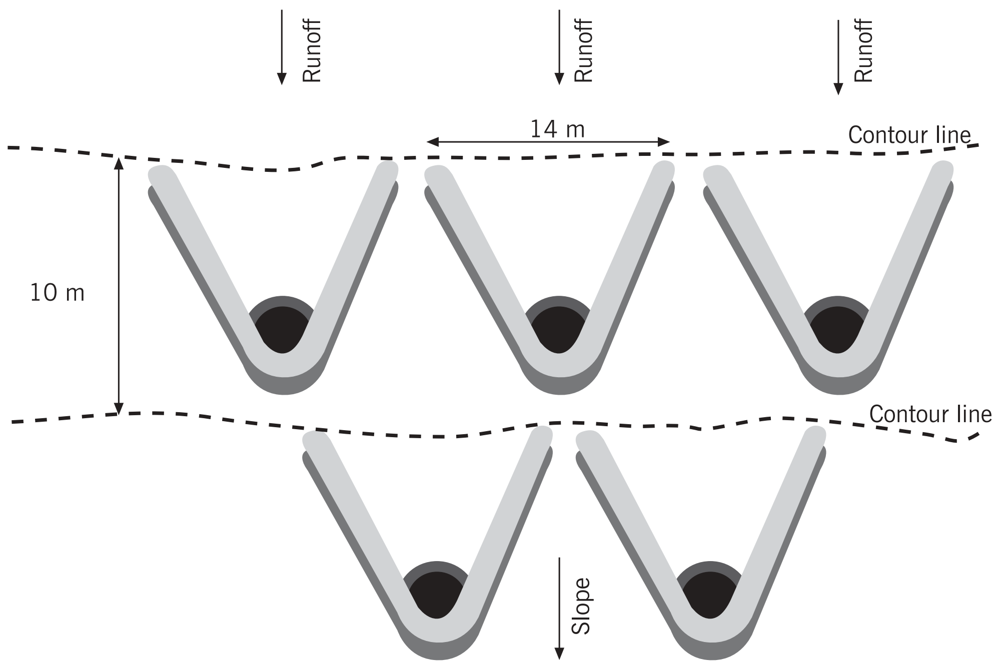


Figure 16. *Triangular micro-catchments.*

Fix the spirit level at the knotted middle point of the string at 7 m. The person who has pulled the string should move up or down the slope until the spirit level bubble is in the centre. That point, point B, should be marked with pegs or stones. A and B are tips or 2 arms of the V-shaped structure. One person should hold one end of the 20-m string at A, the second person should hold the other end of the string at B. The third person takes the knot at the mid point and moves downhill until the string becomes tight and places a stone at this point, C. The string marks the two sides of the micro-catchment and marks the shape by digging lightly along the strings.

Construction of the bunds

Dig some soil from inside, and build the V-shaped bunds on either side. Compact the bund walls by stamping on them and ensure that the bunds are at the same height. Dig a small pit at the inner point of C to catch and store water, which will be used by the plants. The pit can be filled with manure. Plant tree seedlings or crop seeds at the base of the bund on the sides of the pit.

Pitting

Pitting involves construction of small pits of varying width and depth to trap rainwater that falls in to them. Tree seedlings, crops or grass can be planted in these pits. To improve the water-holding capacity of the pits, compost, manure or any organic material should be put in them. In Kenya, enlarged pits have been used for water harvesting in arid areas. The pits are often arranged in a staggered pattern to capture runoff.

Trapezoidal bunds

These are trapezoidal-shaped (four non-parallel sided) earth embankments which are used for enclosing large areas to impound large amounts of water for crop production. Small trapezoidal bunds can be used for growing fruit trees in semi-arid areas.

Layout of trapezoidal bunds

Lay out a row of bunds with the tips touching contour lines. The base of the bund should be along the lowest contour. The embankment is built with soil scooped from both sides. The top of the embankment should be levelled at the tips of the embankment to facilitate overflowing into the next row of bunds.

Size

Because trapezoidal bunds are designed to enclose a large area to impound much more water than the contour bunds mentioned earlier, they are normally bigger both in height and width. Bunds should be 0.8 m high, 0.9 m wide at the base and 0.9 m wide at the top in the central section. At the ends, the bunds should be 0.9 m high and 0.9 m wide at the base. The central section of the bund is typically 10 m long and the distance between the two arms is about 0.9 m. The ratio between the catchment and cultivated area ranges between 15:1 and 40:1.

Operation

The runoff from the catchment areas (hills) is impounded by the arms of the bunds. It fills the enclosed area until it reaches the level of the tips then it overflows and drains into the lower staggered bunds.

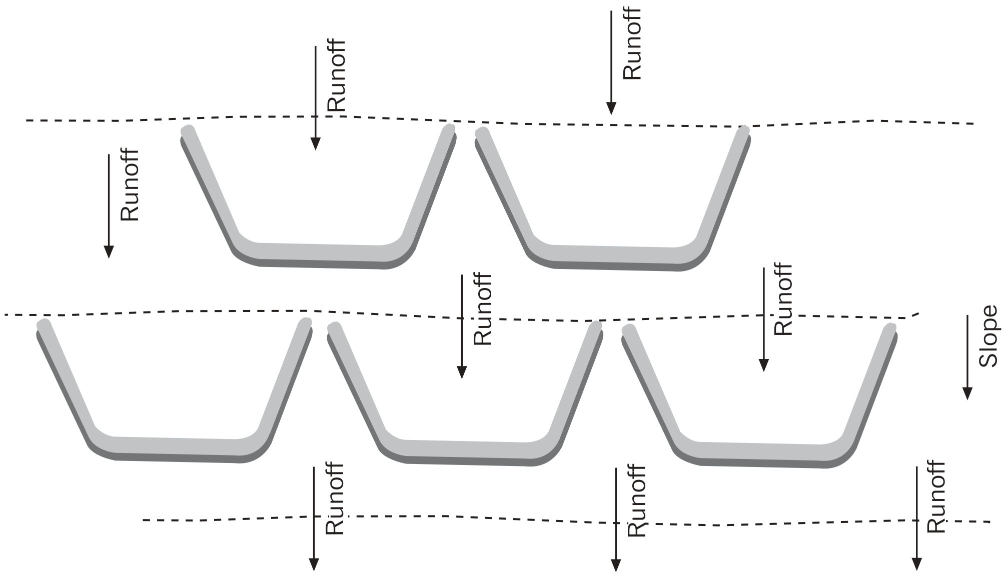


Figure 17. *Trapezoidal bunds.*

Rain-water spreading

This is a technique that involves the construction of structures to divert and spread seasonal flows onto arable land. Structures such as bunds and ridges of stone and earth are constructed at required vertical intervals to slow down the velocity of surface flow and to create a suitable seedbed for planting. To avoid breaches in the structures, emergency spillways are constructed on the bunds. The earth embankments should be about 3 m high. Runoff from roads can also be diverted using channels to the trenches of *fanya juu* terraces to flood cultivated fields. Sandy soils with a low water-storage capacity and high infiltration rates are best for the water-spreading technique.

Runoff concentration

This is a system of directing and concentrating runoff from uncultivated catchment areas directly onto arable land by ridges or channels. The ratio between catchment area and cultivated area within it greatly influences the amount of water concentrated. On average, a ratio of 20:1–30:1 can be used where rainfall is less than 200 mm per annum.

Water harvesting for people and livestock

Water harvesting involves collecting and conserving rainwater from roofs, roads and rock surfaces.

Water pans and underground tanks

These are constructed to collect runoff from homes or institutional compounds, or from roads.

Size

The size of such structures will depend on the volume of runoff and water requirements for livestock, domestic use and for irrigation purposes. An average size is 20 m diameter and 3 m deep. The base and sides of the dug area should be smeared with clay to reduce infiltration and seepage. It could also be lined with polythene sheeting to avoid water seepage. The inlet should have a silt trap to reduce silt accumulation in the pans, which would reduce their capacity. It also helps to reduce the cost of desilting. The top of the pan should be covered with polythene sheeting or timber offcuts to avoid accidents and reduce evaporation. Allowance should be made for discharge of excess water to safer areas to avoid soil erosion. The area should be fenced off to keep out animals that could damage the sides of the pans. Soils with some clay are most suitable for construction of water pans. Sandy soils are not suitable because of the high infiltration rates and the rapid water loss.

Rock catchment

This is a method of harvesting water from bare rocks by construction of embankments which store the rainfall that falls on the rock surfaces.

Roof catchment

This involves collecting water from roofs and storing it in suitable tanks.

Construction of roof-catchment water tanks

It is important to know the following:

- The amount of water required daily for domestic use, for irrigation and for livestock
- The amount of runoff from the roof
- The length of the dry season (how many days without rain).

Some considerations and allowances should be made for loss of stored water through evaporation and wastage.

Calculating the demand for water

- Find out the average daily consumption of water per person and per animal.
- Estimate the number of days in the dry season.
- Find out the number of people and animals using the tank.

Demand (in litres) = number of dry days x consumption per person per animal x number of people and/or animals.

Calculating volume of runoff from roofs

- The area of roof from which the runoff will be collected is found by multiplying its length by its width.
- Find out the annual rainfall from a year with a poor rainy season, or halve the annual average rainfall.

Runoff from roof = annual rainfall x 0.5 x (length x width of roof).

The volume of tank required is, therefore, determined by the demand for water, the amount of rainfall, and the size of the roof (see Table 8). If the roof is too small for the tank required, the only solution is to extend the roof.

Table 8. *Estimating size of tank based on average annual rainfall*

	Rainfall zone					
Roof size (m^2)	550 mm		650 mm		850 mm	
	Volume (m)	Radius (m^3)	Volume (m)	Radius (m^3)	Volume (m)	Radius
30	4.95	0.96	5.85	1.05	7.65	1.20
35	5.78	1.04	6.83	1.13	9.20	1.28
40	6.60	1.11	7.80	1.21	10.20	1.38
45	7.43	1.18	8.78	1.28	11.48	1.47
50	8.25	1.24	9.75	1.35	12,75	1.55
55	9.08	1.30	10.73	1.42	14.03	1.62
60	9.90	1.36	11.73	1.48	15.30	1.69
65	10.73	1.42	12.68	1.54	16.58	1.76
70	11.55	1.47	13.65	1.60	17.85	1.83
75	12.38	1.52	14.63	1.66	19.13	1.89
80	13.20	1.57	15.60	1.71	20.40	1.96
85	14.03	1.62	16.58	1.76	21.68	2.02
90	14.85	1.67	18.53	1.86	24.23	2.13
95	15.68	1.71	18.53	1.86	24.23	2.13
100	16.50	1.76	19.50	1.91	25.50	2.19

Source: RELMA 1997.

6. Agroforestry: tree establishment and management

6.1 Introduction

The products and services provided by trees have always been used in farming. In the past, trees grew naturally on farm lands. The rise in population, and resulting increased demand for wood products, has led to loss of tree cover through cutting down of trees without replacement. Land shortage is common in most parts of Uganda, and therefore land for establishing separate wood plantations is not available. Agroforestry becomes the most obvious and appropriate alternative.

Agroforestry is a term used for land-use systems in which trees or shrubs are grown together with crops or combined with livestock. Trees can be combined with other components, either simultaneously being grown in a field with crops, or in rotation where trees are grown first then cut and replaced with crops. Agroforestry is a technology through which the problems of poor agricultural production, wood shortages and environmental degradation can be addressed.

Trees provide many products such as fuelwood, poles, shade, fodder, fruits, medicine and timber. Trees planted as contour hedges for soil and water conservation help reduce water and soil loss and improve infiltration rate. Trees also maintain soil fertility through nutrient recycling, nitrogen fixation and improving soil structure. Trees are also used as windbreaks, for providing shade and beautifying the landscape.

6.2 Selection of appropriate species

Trees suitable for agroforestry should have characteristics that are highly beneficial to farmers. This usually depends on the technology or tree arrangement desired by the farmer and the final products needed. For instance, a fast-growing aggressive tree species may be very useful for rotational systems but may compete too much with crops.

Table 9. Desirable characteristics of agroforestry trees for selected practices

Tree characteristics	Improved fallow	Boundary planting	Scattered in crop fields	Contour planting
Nitrogen fixing			–	–
Fast growing	–	–		–
Coppicing		–	–	–
Deep rooted		–	–	–
Light canopy		–	–	
Suitable for fodder			–	–
Compatibility with crops		–	–	–
Quick recovery		–	–	–
Lots of biomass	–			–

6.3 Propagation of trees

There are three methods of propagating trees:
- Seed
- Vegetative propagation
- Collecting wild seedlings (wildings).

Propagation by seed

Most trees are raised from seed. Successful raising of seedlings and growing of trees depends on timely availability of good-quality seed. Seed collection should be from trees growing over a large area in a similar ecological zone. The seed is then bulked together into one seedlot and mixed thoroughly.

When collecting seed, the following criteria should be observed:
- Collect only from healthy vigorous trees of good form
- Collect from mature trees; avoid over-mature or immature trees as their seed lose viability very fast
- Collect from as many trees as possible (about 10–30 trees) to widen the genetic base and improve the tree's potential.

Sources of seeds

Seeds can be obtained from:
- Fallen ripe fruits or seeds
- The crowns of felled trees
- Branches cut from standing trees
- Picking fruits or seeds from standing trees
- Commercial and non-commercial suppliers.

Seed handling

The following activities are carried out after seed collection to minimize damage to the seed.

Pre-cleaning

All unwanted material such as bark, twigs and pieces of leaf, is removed from the fruits. This eliminates pests and diseases harboured in the debris and reduces the amount of space required for storage.

Seed extraction

This is the separation of seeds from the fruits. The method used depends on the nature of the fruit. Fleshy fruits are soaked in water until seeds can be separated from the fruit pulp.

Examples of fruit in which seed are extracted in this way are *Polyscias fulva*, *Balanites* spp. and *Prunus africana*. Woody or leathery fruits are first dried until the seeds become detached from the fruit. They are then treated manually or mechanically by tumbling or threshing to separate the dry seeds from the rest of the fruit. Some fruits, mainly nuts, do not require extraction but are sown as fruits. An example is *Delonix regia*.

Seeds such as *Melia azedarach* and *Cordia abyssinica* can be dried directly in sunlight to below 10% moisture content. They are not affected by rapid loss of moisture. Others require gradual drying, preferably in the shade, since they lose viability if dried rapidly because they have thin coats or are small. An example is *Polyscias fulva*. Some seeds need brief sun-drying (1–2 days) then gradual drying (e.g. *Maesopsis eminii, Vitex keniensis* and *Dovyalis caffra*), whereas other seeds lose viability rapidly if dried.

Normally large seeds with a high moisture content when fresh (35–50% moisture) should not be dried at all but sown fresh, e.g. *Bridelia micrantha*. If they must be stored, high moisture levels should be maintained under storage. For example, *Prunus africana* and *Podocarpus latifolius* store quite well in cold, moist sawdust, but this may not be easy under farm conditions.

Seed storage

Storage usually results in a reduced germination rate, but the severity of this effect varies between species. On farm, however, storage should be avoided as much as possible. The period over which seed can remain viable without germinating is greatly affected by:

- The tree species
- Quality at the time of collection
- Treatment between collection and storage
- Conditions under which it is stored.

One of the simplest seed-storage techniques is to put properly dried seeds in sealed containers, such as gourds, bottles, pots or plastic containers, so that they are protected from insects and vermin. The container should be sealed and labelled to indicate the tree species, source and date of storage. Storage should be in a cool place.

Seed pretreatment

Seeds of many tree species germinate readily when grown in moist soil. Other seeds exhibit varying degrees of dormancy and require some form of treatment in order to germinate. There are various ways of pretreating seeds to break their dormancy.

Physical methods

The simplest method is to cut or bore a small hole in the coat of each seed before sowing. Seeds may also be cracked with a hammer, e.g. *Podocarpus latifolius*. The seed coat may also be rubbed away using sandpaper, e.g. *Delonix regia.*

Soaking in water: Soaking seeds in water combines softening hard seed coats and leaching out chemical inhibitors. They must be soaked in water at room temperature for 24–48 hours. For example, *Pinus caribaea* seed should be soaked in water at room temperature for about 48 hours to obtain a good germination rate. Hot-water treatment gives good germination with most leguminous seeds

Table 10. *Seed pretreatment techniques and approximate number of seeds per kilogram*

Species	Seeds/kg	Pretreatment
Acacia albida	9,000	Soak in hot water overnight
Acacia holoserica	70,000	Soak in hot water overnight
Acacia saligna	50,000	Soak in hot water overnight
Acacia senegal	10,000	Soak in hot water overnight
Albizia lebbeck	9,000	Soak in cold water overnight
Azadirachta indica	6,000	None
Balanites aegyptiaca	1,000	None
Calliandra calothyrsus	19,500	Soak in hot water overnight
Casuarina equisetifolia	700,000	None
Cupressus lusitanica	230,000	None
Grevillea robusta	100,000	None
Leucaena leucocephala	25,000	Soak in hot water overnight
Maesopsis eminii	800	Soak in cold water for 24 hours
Mangifera indica	55	None
Melia azedarach	2,000	None
Melia excelsa	500,000	None
Pinus caribaea	30,000	Soak in cold water overnight
Pinus patula	150,000	None
Senna siamea	40,000	Soak in cold water overnight
Senna spectabilis	35,000	Soak in cold water overnight
Sesbania sesban	18,000	None
Tamarindus indica	2,000	With seed coat

Source: Katende et al. 1994; Mbuya et al. 1995.

such as leucaena, acacia, albizia and calliandra. Water is heated to boiling point, removed from the fire and after a short time poured over the seeds in a container and left to cool for about 12 hours. Another way of breaking the dormancy is to alternate wetting and drying of seed. For example, with *Terminalia ivorensis* seed, alternate daily soaking and drying for 7 days gives a germination rate of 50–70%.

Vegetative propagation

Vegetative propagation is an asexual method of multiplying plants. It is possible because all living cells of the plant contain the genetic information necessary to regenerate the entire plant. Roots, stems, leaves and branches all possess this capacity. However, only certain species sprout easily if propagated vegetatively. Some examples are *Ficus* spp., *Erythrina abyssinica* and *Euphorbia* spp.

Use of stem or root cuttings

For some tree species such as ficus and gliricidia, propagation is best done by use of stem cuttings which can vary from 0.5 to 1.5 m in length. The success rate from cuttings depends on how well the stems are able to develop roots, which in turn is affected by several factors:

- Quality of cutting
- The handling of the cuttings
- The season
- Environmental conditions during rooting, with moisture conditions being the most important.

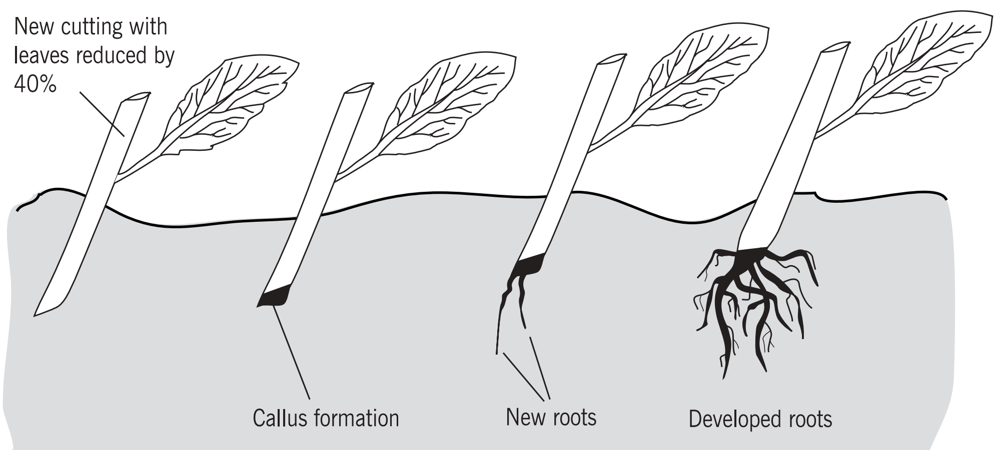


Figure 18. *Propagation from cuttings.*

Grafting

In grafting, two pieces of living plant tissue are joined together in such a manner that they unite and subsequently grow and develop as one plant. The 'rootstock' is a seedling that is already growing and ready to receive a new part (the scion) from another plant. There are various types of grafting: whip graft, cleft graft and crown graft.

Splice grafting

The procedure is as follows:

- Obtain the scion from the growing tip of a branch on the desired plant. The stock should already be an actively growing seedling of the same species.
- Make a clean slanting cut on the lower end of the scion.
- Make a similar cut at the top end of the rootstock.
- Bring the two cut surfaces together and tie them tightly together using polythene tape.
- Keep the grafted plant under shade, and water it regularly until the two portions fuse together.
- When the scion sprouts new leaves, all growth on the rootstock portion should be removed.

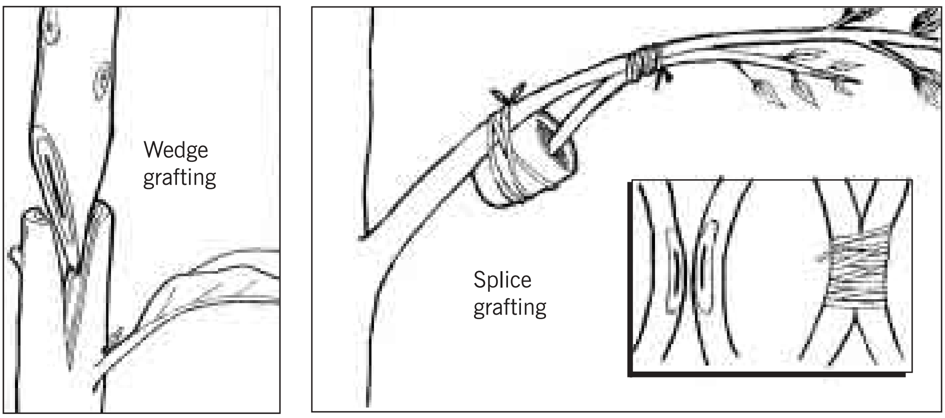


Figure 19. *Propagation by grafting.*

Budding

Budding is a method of propagation in which a lateral bud from a desired superior tree is inserted into another plant that serves as the rootstock. It is similar to grafting in involving the fusion of living tissue but the scion material is a bud. Budding can be performed in various patterns, for example the T- or inverted T-bud, which is sometimes called the shield-budding pattern. Other kinds are patch, top and chip budding.

The procedure is as follows:

T- or shield budding

- Prepare the rootstock by removing all the leafy material below the budding point, which should be at least 25 cm above the ground.
- Use a sharp knife to make a vertical cut into the bark about 3 cm long, ensuring you do not cut into the wood.
- Next make a horizontal cut at the upper end of the vertical cut, thus forming a T.
- Now open out the cuts at the upper end.
- Cut out a shield-shaped piece of the scion, including the bud, and insert it into the T-shaped cut on the rootstock plant. The scion should be about 2 cm long.
- Use polythene tape to firmly tie the insertion, starting from the bottom but *not* covering the bud itself.
- Remove the polythene after 2–3 weeks.
- Inspect the bud after another 2 weeks. If it is green, it has taken and the rootstock plant can be cut 20 cm above the T insertion to stimulate the new bud to grow. If the seedling is brown, then it is dead and the grafting must be repeated.
- After the bud has grown to 20–30 cm long, cut off the remaining rootstock stub 2 cm above the new bud.

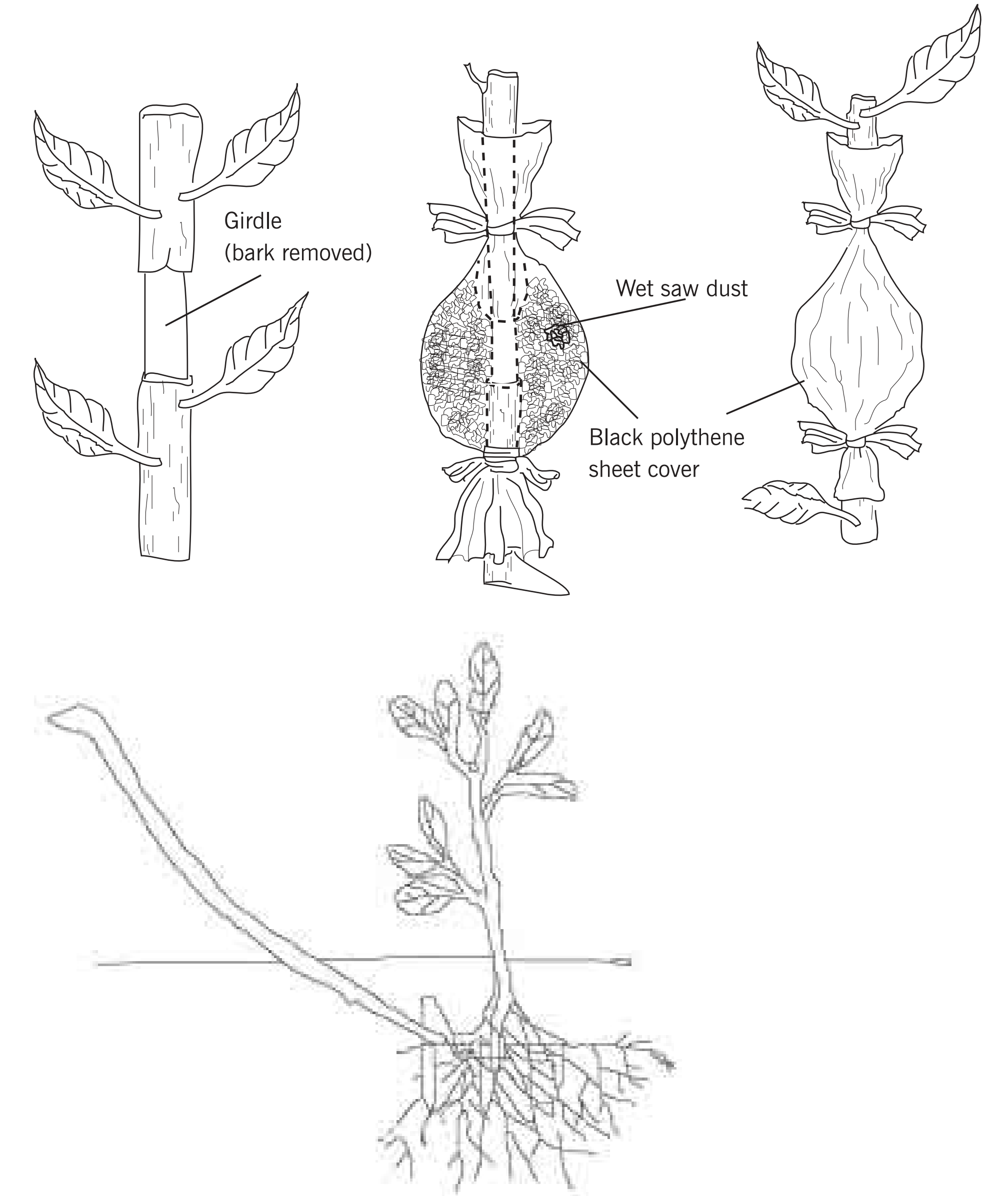
Inverted T-budding

The procedure is the same as for the T-budding described above, except that the horizontal cut is made below the vertical cut.

Figure 20. *Propagation by budding.*

Propagation by layering (marcotting)

This is a method by which adventitious roots are made to form on a stem while it is still attached to the parent plant. The rooted stock is later detached and potted or planted. It is genetically identical to the mother plant. Types of artificial layering include air layering, mound layering, and trench layering.



Source: Mudge et al. 1992.

Figure 21. *Propagation by layering.*

It is thus important that the following are kept at optimum levels:

- Air temperature
- Soil temperature
- Humidity of the air
- Light (intensity and quality).

These conditions are easily maintained by use of equipment called a vegetative propagator. A propagator can be a simple polythene cover placed over the cuttings. Cuttings are delicate living materials that will die easily if environmental conditions are unfavourable, even if only for a short period.

6.4 Establishment and management of small-scale tree nurseries

These recommendations focus on basic small farm nurseries with simple equipment. Some ways of raising seedlings in a nursery are the following:

Bare-rooted seedlings

These need:

- Raised seedbeds
- Good subsoil
- Sand on top
- Only plant out into the field under good conditions (moisture, cool/cloudy weather).

Potted seedlings

- Seeds are sown directly in pots, 2–5 seeds per pot. Seed must be sufficient and of reasonable quality. Thinning to one seedling per pot is done later.
- Alternatively, seeds are sown first in seedbeds or germination boxes, then they are pricked out into pots.

Nursery site

The site should always be near a permanent water source such as a stream so that water is available all the year round. The site should always be on flat land which is not exposed to drying winds. It should also have well-drained and fertile soils. However, it may not require a great deal of water to maintain a home nursery as the number of seedlings is generally small.

Nursery soil (the medium for germination)

The soil for germination beds does not need to be rich in nutrients. Pure sand or any other medium can be used as long as other suitable conditions are provided, especially optimum temperature and water. However, the transplant beds must have soil that is rich in nutrients to give the young plants a good start. The potting soil should be rich in nutrients and is usually imported. This eliminates the need for manure or fertilizer. Some trees such as *Pinus* spp. require topsoil from beneath trees of the same species to give them a good start.

Seedbeds and seedling containers

The nature of the seedbed depends on where tree planting is being done. Raised beds should be used in areas with high water-tables, sunken beds in semi-arid areas, and flat beds in well-drained soils. Seedbeds should align in an east–west direction to minimize the effect of the sun shining directly onto the seedbeds. Before sowing, a layer of clean sand can be applied to the seedbeds.

Several types of containers can be used. Polythene tubes with one closed end help conserve water and ensure better protection for the seedlings during transportation. They are usually used in wet areas. The other type is the open-ended polythene tube. Other types of containers are milk packets, banana leaves and tins. Holes are poked in the bottom to improve drainage. Milk packets should be washed out with water followed by old engine oil to prevent termite and fungal attack. The aim should be to use cheap, locally available materials.

Sowing

Small seeds may be sown by broadcasting in the germination bed and transplanted after the first three leaves have appeared. Very small seeds like those of *Eucalyptus* spp. should be mixed with fine sand during sowing to ensure even distribution on the seedbed. This also helps avoid overcrowding of seedlings after germination. Large seeds may be sown directly into pots. Examples include *musisi* (maesopsis), albizia, melia and leucaena. Two seeds are sown per pot, then one of the seedlings may be transplanted to another pot later.

Pricking out and shade

Preferably, pricking out should be done when seedlings have attained a height of about 5 cm. This helps the seedling to establish better as long as its roots are still small enough to be accommodated by the pot. Usually smaller seedlings do not require root pruning before potting. When pricking out, the roots should not be bent and the young pricked-out seedlings should be kept moist.

Shade is essential for preventing water loss and excessive build-up of heat in the containers. Natural shade can be used if the seedbeds are sited under trees. It can also be provided in the form of a wooden frame on which grass, banana leaves, mats or sacks can be laid. The shade should be removed about two weeks before the seedlings are to be planted out. The slope required for this shade cover will depend on the position of the sun. In the southern hemisphere, the roof is slanted southwards, and in the northern hemisphere it is slanted to the north.

Protecting seedlings from diseases and pests

Soil with a high organic-matter content usually contains many cutworms. Sometimes a pesticide can be applied to the soil to kill these pests. A kind of fungus which favours alkaline soils causes a problem called damping off. Protect seedlings from damping off by keeping seedbeds well drained and avoiding excessive heat. Rats will not come to a nursery that is kept clean and free of rubbish.

Preparing seedlings for planting

Before seedlings are planted out, they should be hardened off. This means becoming accustomed to scarcity of water. This is done by gradually decreasing the frequency of watering in the nursery until eventually the seedlings are watered only when the soil in the pot is almost completely dry. The seedlings are also adjusted to intense sunlight by gradually removing the shade, hence leaving them in direct sunlight for about 2 weeks before planting out time. Root pruning of seedlings in containers also becomes more frequent than before (once a week). The hardening-off process should start 1 or 2 months before the expected time of planting out.

Transport of seedlings from the nursery

If this is not carefully done, it can lead to loss of many seedlings. To avoid the hazards of a long journey, it is good practice to raise the seedlings near the planting site. Seedlings must be thoroughly watered at the nursery beforehand. They are watered again immediately on reaching the planting site and planted soon afterwards. Preferably, this should be after a heavy downpour, especially for bare-rooted seedlings. This ensures that the seedlings have enough water for initial establishment. Keep them under shade at the planting site.

6.5 Establishment and management of trees

Land preparation

This involves slashing, ploughing and digging pits. Most agroforestry tree species grown simultaneously with crops do not require separate slashing and ploughing as the land is already prepared for agricultural crops. Farmers very rarely plough the land for separate woodlots, although this does help trees to establish quickly in a field. Preferably, the pits should be dug before the seedlings are brought to the planting site. The pits should be wide and deep enough for seedlings to be planted without bending the taproot.

Handling of the seedling

The seedling should be removed carefully from the pot before placing it in the pit. The pit is then refilled with topsoil. The soil is pressed firmly around the seedling, making sure the seedling is upright. Watering should be done immediately.

Weeding

Weeding is essential to reduce competition from weeds and damage by other organisms that take advantage of the presence of weeds and should be done regularly, especially at the beginning of the rains. Where it is uneconomical to weed the whole area, spot weeding should be carried out. Where trees are grown with crops around the trees, the trees are weeded at the same time as the crops.

Protection of young trees

Trees need protection from rodents, browsing and trampling animals, and fire, especially while they are still young. Important measures to avoid damage are:

- Rodents: Clean-weed or slash the area.
- Animals (domestic or wild): Fence off the whole area or individual trees.
- Fire: Slash vegetation around the trees or along the boundaries of the area where there are trees. Roads can also be used as firebreaks. Advise the public on fire-prevention measures.
- Pests: Trees can be protected from insects by planting resistant varieties or species, mixing different species, use of agrochemicals, use of biological-control or integrated pest-management methods.
- Diseases: To avoid diseases, plant trees in well-drained soils, keep the area around the trees clean and remove and burn dead tree stumps on the site. You can also use agrochemicals.
- Humans: Sensitize communities and individuals on the importance of trees. Educate people on the need to protect trees.

Pruning

This involves removing live branches from a growing tree using a saw or panga (machette). Some trees such as eucalyptus are self-pruning and therefore do not need pruning by the farmer. Pruning is done to:

- Obtain tree products, e.g. fodder, firewood
- Encourage development of a clean bole
- Reduce shade on crops.

Thinning

Thinning is the removal of some of the young trees in order to allow the remaining trees to grow bigger and reach the required size quickly. Trees that are poor in form, bent or dying are also removed. Thinning helps to reduce competition and encourages increase in girth of the best trees. The trees removed in this way can then be used for fencing or fuelwood. In a woodlot, it may be necessary to replace seedlings that have died. This is called ‘beating up’. It should be done as soon as possible to ensure uniform growth.

Pollarding

Pollarding is the cutting back of the entire crown at 4–6 m height but leaving the main stem so that multiple branches can sprout from the stem at some distance from the ground. Pollarding is done to harvest fodder, fuelwood and small-sized wood for construction, to reduce shade on crops, and to encourage good timber production. Not all tree species respond to pollarding. Commonly pollarded trees are *Grevillea robusta* and many of the species growing in semi-arid areas.

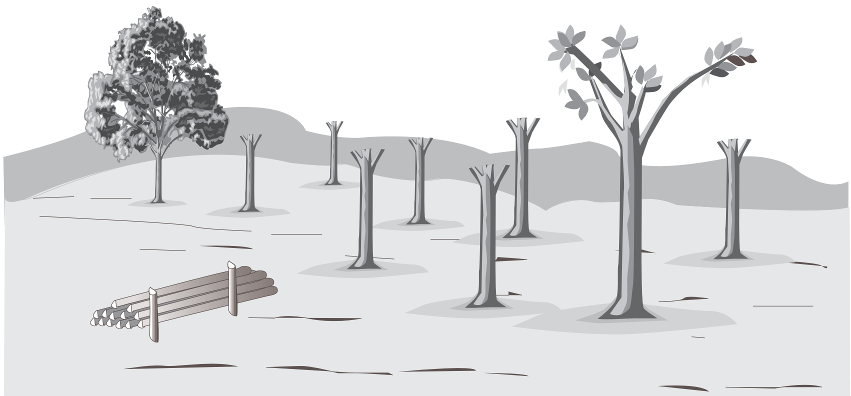


Figure 22. *Pollarding.*

Coppicing

Coppicing is cutting the main stems close to the ground to encourage new shoots to sprout.

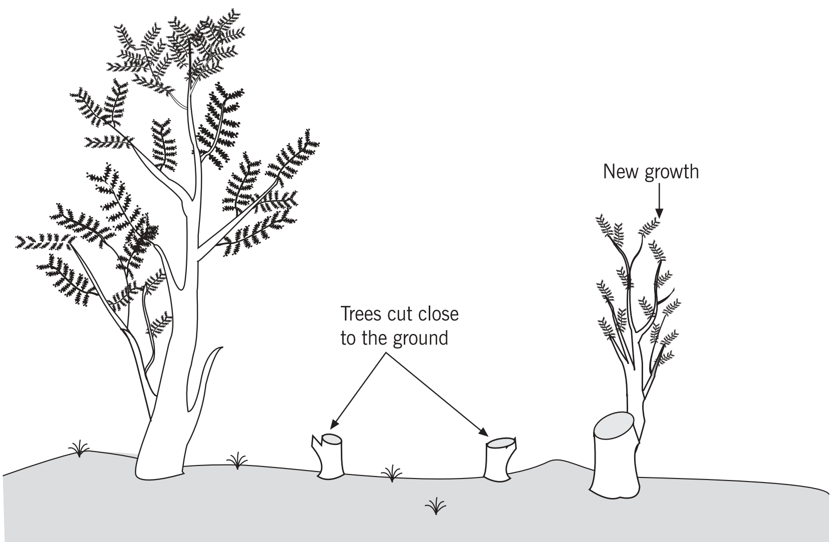


Figure 23. *Coppicing.*

The advantages of coppicing are:

- There are no replanting costs
- Rapid growth suppresses weeds
- Regrowth is quick and provides repeated harvests of tree products such as fodder, poles and fuelwood.

6.6 Agroforestry technologies and planting patterns

Several systems or patterns of tree planting have been identified on farmers' fields in Kabale. Some common agroforestry practices are:

- Scattered trees in fields
- Contour hedges for soil conservation
- Woodlots
- Trees on rangeland and pasture
- Trees in homegardens
- Rotational wood fallows
- Fodder banks
- Live fences.

Trees scattered in crop fields

This is a very common agroforestry practice in most parts of the country. The trees are found scattered in crop fields, with or without any particular pattern. They are grown for production of various products such as poles, firewood, fruit, timber, fodder and medicine. For example, cashew nuts, shea butter trees and mangoes are commonly found in the north and eastern parts of the country. In central Uganda, jackfruit, avocado and *Markhamia lutea* are common in crop fields. In the Kigezi highlands, tree species grown in crop fields are *Markhamia* spp., *Ficus natalensis* and *Euphorbia* spp. Recently, *Grevillea robusta, Alnus acuminata* and *Sesbania sesban* have also become common.

Management of trees scattered in crop fields requires reducing the shade by pruning of branches and the tops, especially for *Grevillea* and *Ficus* spp. Sometimes, there may be a need to leave the shade for adjacent crops such as coffee and bananas.

Contour hedges for soil conservation

Contour hedges consist of trees planted along contour bunds, with or without grass strips. This practice is found in the highland areas of Kabale, Mbale, and Kapchorwa Districts. The trees and shrubs planted on steep slopes can significantly reduce the speed of water and soil movement. The most commonly used species in the highlands of Kigezi are *Calliandra calothyrsus* and *Leucaena diversifolia*. The hedges are planted at close spacing, i.e. 50 cm between trees, and need to be pruned when the crops are mature. The pruning is carried out periodically at 50-cm or knee height. This reduces competition for light and water and makes adjacent crops grow faster. Prunings can be used as fodder, green manure or staking materials.

Live fencing

Living trees, such as euphorbia and *Dovyalis caffra* (Kei apple), are used for fencing gardens to protect crops from damage by livestock. A close spacing of about 30 cm can be used. Pruning is recommended where crops may be grown adjacent to the hedge, but should not allow the intrusion of annuals.

Woodlots

Woodlots, either of single tree species or a mixture of species, are established usually for fuelwood, poles and sometimes timber. In Uganda, the common species used are eucalyptus, *Pinus* spp. and *Cupressus lusitanica.* In the Kigezi highlands, *Alnus acuminata* and *Grevillea robusta* are used for planting woodlots. The major limitation of this system is the shortage of land, since food crops usually take precedence over trees. Woodlots are more common in areas where land is abundant or where crop production has failed and is not profitable. In the Kigezi highlands, trees are commonly grown in the most infertile steep areas and waterlogged places.

Initial spot weeding may be needed, as well as protection from fires by creating a clean-weeded firebreak around the woodlot when the dry season is approaching. The degree of thinning to be carried out is determined by the final intended use of the woodlot.

Trees on pastures and rangelands

Here, trees are either scattered randomly or arranged according to some systematic pattern on established pastures or rangelands. The trees usually provide shade and fodder. Grass also tends to grow better under such trees. Some of the common species are *Acacia* spp., *Ficus* spp., *Alnus acuminata* and *Euphorbia* spp. The practice is common in areas of extensive grazing land. It is usually difficult to protect the young trees from livestock and fire.

On pasture land, trees should be given time to establish before cows are allowed in. Otherwise, the area with young trees should be fenced off. The young trees can also be protected individually.

Trees in homegardens

This practice is common in areas of high population density such as those bordering Lake Victoria. Trees or shrubs are grown in close association with annual and perennial crops within the compound of individual homesteads. Fruit trees such as avocado (*Persea americana*), mangoes (*Mangifera indica*) and tree tomatoes (*Cyphomandra betacea*) usually dominate, but other woody species such as *Ficus natalensis*, *Markhamia* and *Maesopsis* spp. and *Erythrina abyssinica* are also common. The food crops normally grown under such trees are shade tolerant. If not, some of the tree branches should be cut to reduce the shading effect.

Trees in homegardens are managed conveniently with the associated crops in the garden.

Rotational wood fallow

Fallows are used to revitalize exhausted soils. While natural fallows take a long time to restore soil fertility, nitrogen-fixing trees or shrubs can be used to shorten the fallow period required to restore soil fertility. These improved fallows should include such leguminous species as *Sesbania sesban, Leucaena* spp. and calliandra. These trees are grown for several years, after which they are cut and replaced with a food crop. Other useful products such as firewood and stakes can be obtained. The trees should be established at close spacing to encourage quick production of large amounts of biomass and to suppress weeds. Usually the trees will establish faster if protected from animals. Initial weeding is necessary to give the trees an advantage over the weeds.

Fodder banks

Fast-growing fodder tree species such as leucaena, calliandra and gliricidia are planted in a block on their own or in a mixture with fodder grasses for cut-and-carry fodder production. They can also be planted along contour bunds. These trees have a high level of protein in their leaves, which is beneficial for milk production. For example, work by ICRAF has shown that 3 kg fresh calliandra leaves will increase one cow's milk production by 0.5–1.0 litre per day. In other words, calliandra can largely replace commercial concentrates for feeding dairy cows. The practice is common in areas where land is scarce and population density is high.

Management mainly involves cutting of the leaf biomass to encourage more growth. Sharp tools should be used to avoid injury to the fodder trees during this periodic harvesting.

6.7 Energy conservation

Even if there is a good supply of trees, it is important to use them in the most economical way as a source of energy for cooking and heating. Conserving energy for household use requires the use of both technical and non-technical methods.

Non-technical options

Improved cooking practices are often recommended as a major measure in household energy conservation. There are a number of ways to save fuel. The cooking process consists of three major components: the fuel, the fire and the cook.

The fuel

When woody fuels are used for cooking, they must first be dried. Use of dry wood reduces the amount of energy that would otherwise be used to dry the wood. Firewood should be chopped into small pieces in order to dry faster and to improve combustion efficiency if a flame fire rather than a charcoal fire is required.

The fire

The fire may be lit in a three-stone hearth or an improved stove. Before lighting, the stove or hearth should be cleared of the ash remaining after the last cooking. Generally, when high temperatures are required to bring food to boiling point, the firewood should be supplied with sufficient air in order to produce a fierce flame. Once the food has boiled, it only needs to be simmered using a lower temperature. This can be achieved by supplying quantities of air and firewood just sufficient to keep the liquid boiling. This is normally difficult to do with the three-stone hearth, especially if the fire is lit out of doors, but many improved stove models can do this. Maintaining lower temperatures is very important for foods that cook for more than 15–20 minutes. Cooking in an enclosed shelter can contribute to conserving firewood. This is especially important in windy places and where there are no kitchens.

The cook

The cook is the most important part of the cooking process. A cook's ability to prepare the firewood and manage the fire for cooking is a major factor in energy conservation and avoiding wastage. The cook, therefore, needs to do the following:

- Plan the meal to avoid a time lapse between preparation of different dishes. For instance, peeling and chopping should be done before making the fire.
- Soaking dry foods such as beans, maize and peas overnight reduces cooking time, thus reducing the amount of fuel used.
- Cutting food into small pieces hastens cooking. This is one of the major options for reducing cooking time and consequently lowering total fuel consumption.
- Steaming requires lower temperatures than stir-frying, although in some cases stir-fried food cooks faster. In addition, steaming reduces the cook's exposure to pollutants from the fire which may be detrimental to his or her health. Steamed foods are healthier than fried foods since a high intake of fats and oils contributes to causing many diseases.
- Double cooking involves cooking two or three dishes on one fire by placing a second and third pan on top of the first. The preparation of *matooke* in banana leaves often involves double cooking. Foods such as groundnut stew or vegetables can be cooked along with green bananas (*luwombo*). Water for adding to the food being cooked can be warmed by placing a larger saucepan on top of the pan on the stove. Double cooking must be done on a stable stove to avoid accidents, particularly when there are children in the house.
- Covering pots and pans with lids reduces the amount of heat lost through evaporating water. When lids are not available, the double-cooking option can be used.
- Using a fireless cooker for part of the cooking process reduces the fuel required. The fireless cooker is a simple device that can be made from a basket

or old box. The basket/box is lagged with old newspapers or clothes and covered with sacking. A cover for the box or basket is also made. The lagging should be about 5 cm thick. Once the food has boiled in a covered saucepan, it is removed from the fire and placed in the fireless cooker for the required period.

Technical options

Work on improved stoves in Uganda was initiated in the 1980s by local and international NGOs and enterprises in the private sector. Many types of such fuel-saving stoves are currently being promoted in Uganda. They are designed to use charcoal, fuelwood and waste materials such as sawdust and coffee husks. The most commonly used improved stoves in Uganda are the Uganda ceramic stove, the Kabale stove and the Black Power charcoal stove.

The Uganda ceramic stove

This is a metal stove with fired clay liners and it has an efficiency of 27%. This stove can be obtained in some markets, and from a number of grocery stores in Kampala as well as from street vendors. They can also be obtained from USIKA Crafts Ltd. and the YWCA. The YWCA has a number of clubs in the rural areas where the stoves may be obtained.

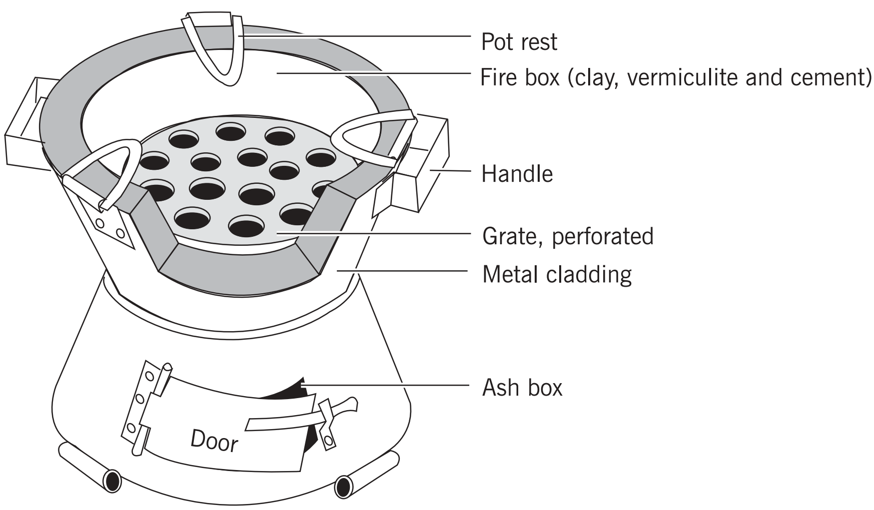


Figure 24. *The Uganda ceramic stove.*

The Kabale stove

This is a stove with a fired clay liner and has an efficiency of 20%. The Kabale stove is available in most markets in Western and Central Uganda.

The Black Power stove

This is another metal stove with a fired clay liner and has an efficiency of 33%. It can be obtained from Black Power Uganda Ltd.

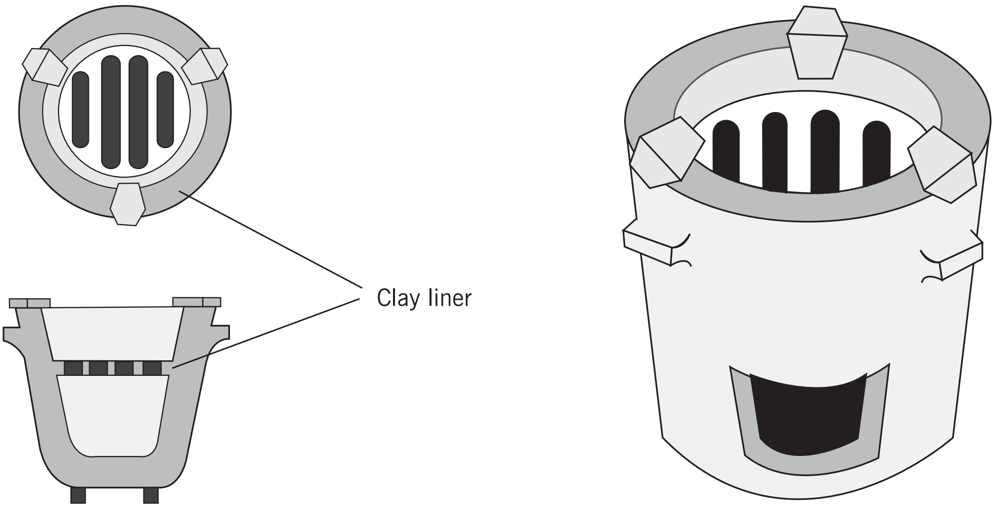


Figure 25. *The Kabale stove.*

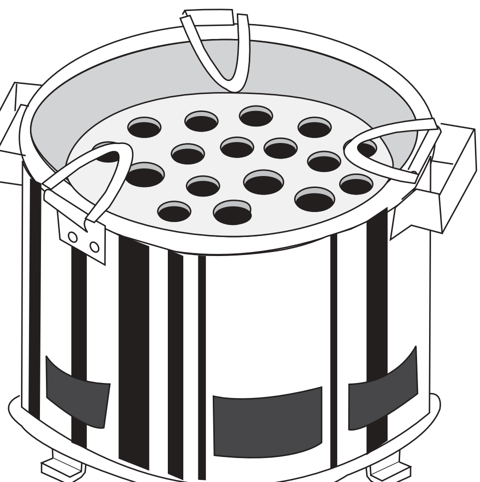


Figure 26. *The Black Power stove.*

There are a variety of other fuel-saving stoves such as the Nnalongo, Fica, Dembe, Louga, Lorena and Y-stove.

7. Livestock management

7.1 The role of livestock in land-resource management

Livestock production provides a livelihood for many households. There are great possibilities for the generation of a wide range of products for the local, regional and international markets. Incorporating livestock as an enterprise on a farm will provide a use for converting by-products of this farming system into high-value products—namely milk and meat. Other livestock products that can be obtained include hides and skins, horns, gall-bladder stones, all of which can be exported. Animal manure is important because it reduces the use of chemical fertilizers and increases soil organic matter content, leading to improvement of soil structure and soil fertility. Biogas can also be produced from manure (for cooking fuel and for lighting).

Incorporation of fodder plants such as elephant grass or leguminous herbs or shrubs not only improves the availability of fodder but also contributes to soil conservation and soil fertility. Fodder grasses planted along contours can effectively reduce erosion. Many leguminous plants have the ability to fix atmospheric nitrogen, a most valuable feature for maintenance of soil fertility. However, many of these species effectively fix nitrogen only if the soil contains a sufficient level of phosphorus. Therefore, mixed farming with a balance between crop production and livestock rearing offers great potential for high productivity while still maintaining or improving soil fertility and structure.

Stall feeding (or zero-grazing) is becoming increasingly popular and this means keeping fewer and more productive animals. This reduces the negative effect of livestock on the land, which is often overgrazed due to overstocking, in turn leading to soil erosion. With intensified management under zero-grazing, the productivity of the livestock also increases.

7.2 Choice of appropriate livestock

There are indigenous, exotic and crossbreed dairy cattle. The milk-producing potential of both indigenous and exotic dairy cattle can be fully manifested with improved environmental conditions and husbandry. Indigenous cattle have the advantage of being well adapted to local conditions as well as having greater resistance to many diseases.

Areas suitable for indigenous breeds of cattle are:

- Where extensive grazing is possible
- Areas with unreliable rainfall and poor soils
- Where milk prices are low
- Where feeder roads are bad
- Where management is poor.

In areas with generally reliable rainfall and relatively good soils, or in areas surrounding major towns, stall feeding or zero-grazing are recommended as the demand for milk is high and it can fetch good prices. The dairy breeds recommended for this grazing system are exotic or crossbred types with a high potential for milk production. These breeds are large consumers of forage and water and are less resistant to diseases than indigenous breeds. This calls for significant improvement in management, proper disease control and adequate feeding. Currently in Uganda, it has been shown that this is possible even for the smallholder farmer with limited resources.

The choice of breed should therefore be based upon:

- Farmers' preferences
- The ability to manage and provide sufficient feed
- The availability of stock.

Dairy goats are an appropriate type of livestock in areas where land is a limiting factor. About a quarter of an acre is sufficient for growing the required fodder for each adult animal. Farmers with much less land are growing feed for dairy goats in the hilly areas of Kasese District. In addition to planted fodder, browse from trees and shrubs provides additional feed for goats. Milk production from such goats is 2–5 litres per day, enough to meet family requirements with some surplus for sale. Dairy goats are relatively economical in terms of feed, housing and veterinary care (see Section 7.9).

7.3 Grazing systems

There are three common grazing systems in Uganda today:

- Continuous grazing
- Rotational grazing
- Zero-grazing.

Continuous grazing

This is an extensive system of grazing where animals are left on the same pasture area for prolonged periods. This is common in most of the pastoral (communal grazing) areas of Mbarara, Teso and Karamoja. It has led to overgrazing and resulting land degradation. To improve the productivity of these areas and conserve the land resources, the communities should:

- Be sensitized to the importance of their environment and its sustainability
- Institute their own by-laws aimed at conserving the environment
- Be mobilized to oversow the natural pastures with forage legumes.

Rotational grazing

This is a more intensive method of grazing management aimed at making maximum use of pastures. This system involves fencing and paddocking, that is, moving animals from one piece of pasture to another in a more or less regular and systematic manner. This system of grazing aims to:

- Allow the vegetation to regenerate sufficiently to provide further pasture and fodder and protective cover for the soil
- Prevent erosion caused by excessive trampling
- Reduce the build up of potential disease vectors and parasites.

The smaller the area on which the livestock are concentrated, the more efficient the herbage utilization. Cheap fencing can be made using live fences of species such as *Euphorbia tirucalli* or *Agave sisalana*. A three-paddock system in which pastures are grazed for two weeks and rested for four weeks (a total of six weeks) is recommended.

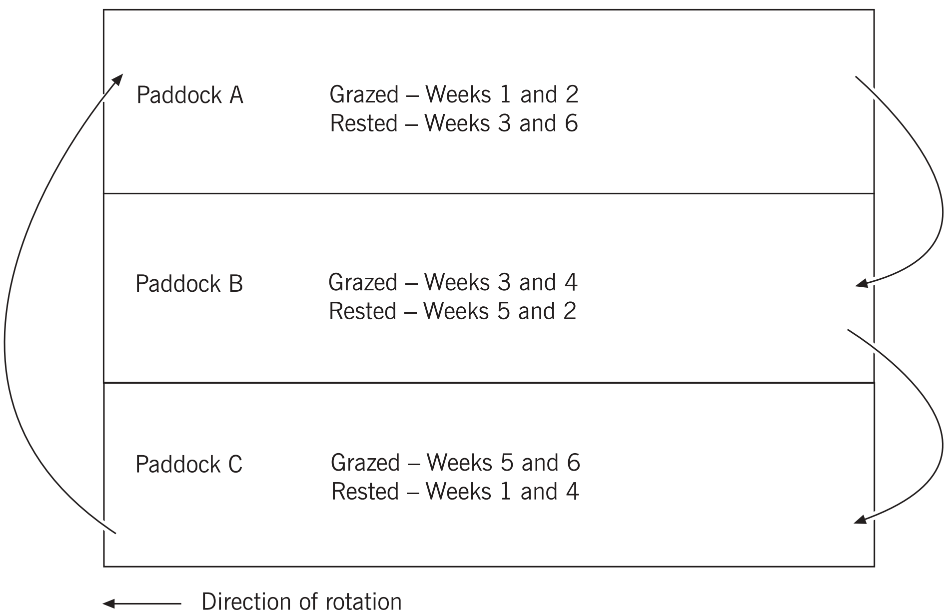


Figure 27. *Rotational 3-paddock grazing system.*

Zero-grazing system

This is a system under which high-value animals, especially dairy cattle and milch goats, are confined in a shed or yard and feed is brought to them. The system is very popular in peri-urban and highly populated areas where land for open grazing is limiting. Under zero-grazing, production per land unit is increased. For instance, 0.6 ha of good pasture will support one cow, while the same amount of land under elephant grass for zero-grazing can support 3–4 cows. Manure and bedding from a zero-grazing stall can be used to improve soil fertility. Zero-grazing is, however, labour intensive with high capital costs for erecting the shed, buying essential drugs, including acaricides, and any other inputs in the initial stages. The zero-grazing unit shown in Figure 28 should be constructed using locally available materials.

Stocking rates

The manipulation of stocking rates is one of the most effective means of improving pasture/range productivity in terms of milk and liveweight gains. Other factors such as water supply, labour and fertilizers are also important. The recommended stocking rate for those areas that have fairly fertile soils and rainfall over 850 mm per year is 2 cows per hectare. In drier areas (rainfall below 850 mm and with less fertile soils), the recommended stocking rate is 1 cow per hectare.

7.4 Establishment and management of forage species

Different species are adapted to different soils and climatic conditions. Table 11 gives a list of species likely to succeed in each area of Uganda, and the grass/legume mixtures that have been successful in those areas. Most of the grass species are indigenous to Uganda and, where these occur, it is only necessary to remove weeds and oversow with legumes to improve the quality of the pasture. (See Appendix III for local names of the grass and legume species in Uganda.)

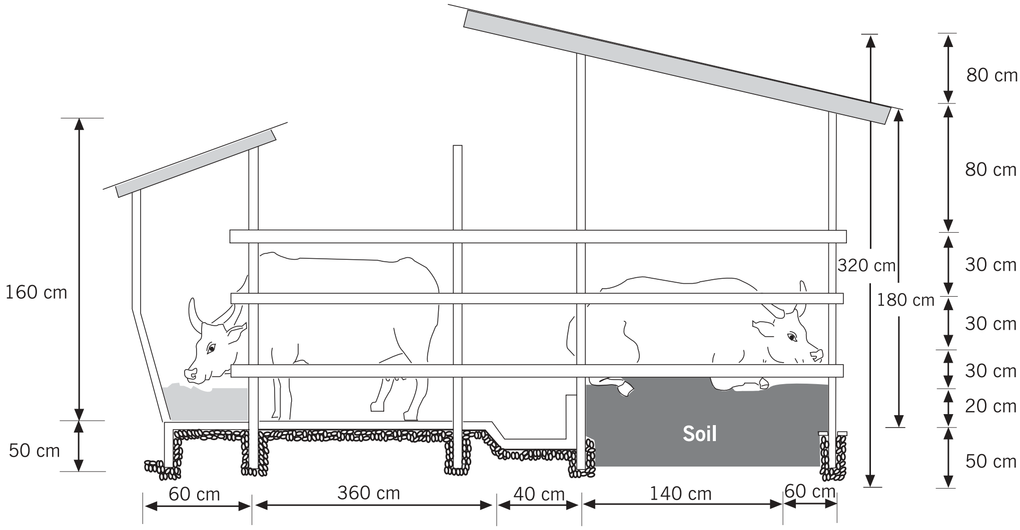
Improvement of natural pastures

A range of actions can be considered for improvement of natural pastures:

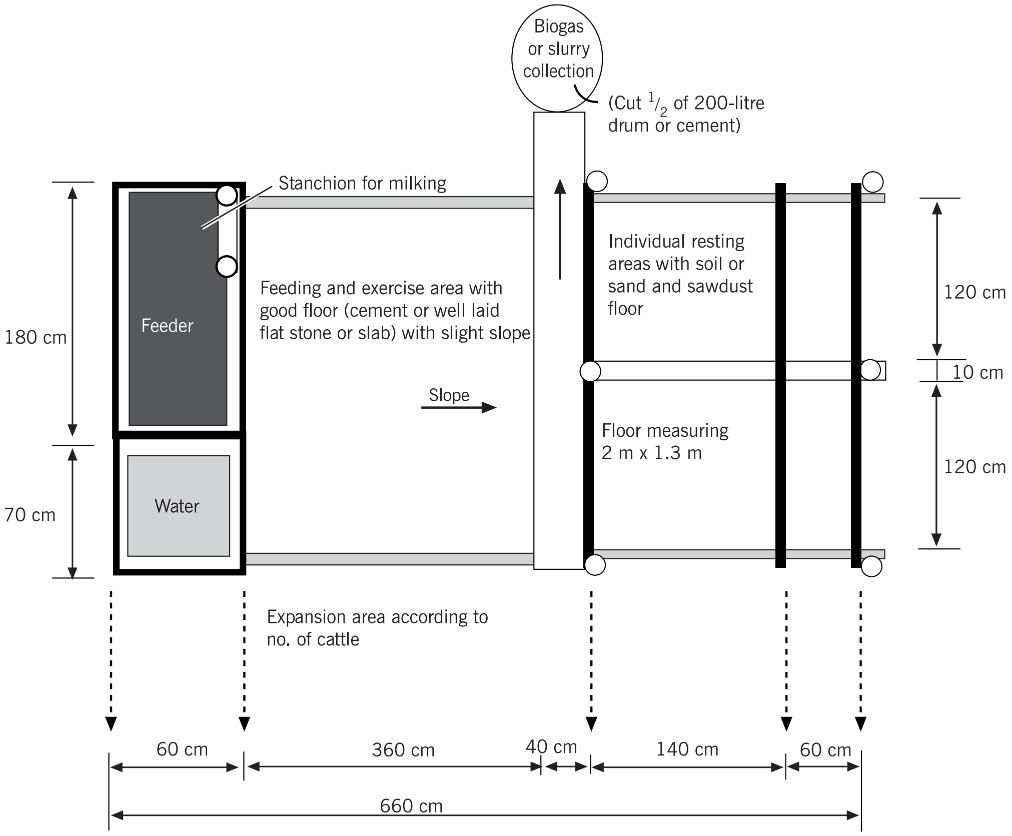
- Perimeter fencing
- Paddocking
- Weeding to reduce competition
- Oversowing with legumes
- Management through controlled grazing.

Perimeter fencing

Perimeter fencing using barbed wire or live fences is a prerequisite for improvement.



Simple free-stall cattle shed viewed from the side



Simple free-stall cattle shed viewed from above

Figure 28. *Zero-grazing unit for dairy cows.*

Table 11. *Recommended grasses, legumes, fodder species and other mixtures*

District	Grasses	Legume	Fodder	Grass/legume mixture
Kabarole Kasese	*Panicum maximum* *Chloris gayana*	*Desmodium intortum* *Desmodium uncinatum*	(i) *Chloris gayana* Setaria	*Panicum maximum*
Mbale Kapchorwa	*Brachiaria ruziziensis* *Pennisetum clandestinum*	*Neonotonia atropurpureum* *Stylosanthes guyanesis* *Trifolium repens*	(ii) Chloris, Brachiaria, white clover or siratro	*Brachiaria ruziziensis* *Chloris gayana* *Pennisetum clandestinum* *Desmodium intortum* *Neonotonia wightii*
Tororo Soroti Kumi Gulu Lira Arua Nebbi Moyo Pallisa	*Chloris gayana* *Panicum maximum* *Hyparrhenia rufa* *Setaria anceps*	*Centrosema pubescens* *Neonotonia atropurpureum* *N. wightii* *Stylosanthes* spp.	(i) *Chloris gayana* *Pennisetum purpureum* *Dolichos lablab* *Tripsacum laxum* *Cajanus cajan*	*Panicum maximum* *Stylosanthes* spp. (ii) *Chloris gayana* *Hyparrhenia rufa* *Centrosema pubescens* (iii) *Chloris gayana* *Setaria anceps* *Centrosema pubescens*, *Neonotonia wightii*
Kampala Jinja Mukono Mpigi Masaka Mubende Luwero Iganga Kamuli	*Chloris gayana* *Panicum maximum* *Brachiaria brizantha* *Setaria anceps* *Cynodon dactylon*	*Centrosema pubescens* *Desmodium intortum* *Desmodium uncinatum* *Macroptilium atropurpureum* *Neonotonia wightii* *Aeschynomene americana*	*Pennisetum purpureum* *Tripsacum laxum* *Dolichos lablab* *Cajanus cajan* *Setaria splendida* *Leucaena leucocephala*	(i) *Chloris gayana* *Panicum maximum* *Centrosema pubescens* *Desmodium* spp. (ii) *Brachiaria spp.* *Setaria anceps* *Chloris gayana*, *Desmodium* spp. *Macroptilium atropurpureum* (iii) *Chloris gayana* *Brachiaria* spp. *Neonotonia wightii* *Macroptilium atropurpureum* (iv) *Chloris gayana* *Cenchrus ciliaris* *Stylosanthes* spp.
Mbarara Bushenyi Rakai Rukungiri Ntungamo	*Chloris gayana* *Brachiaria ruziziensis* *Themeda triandra* *Panicum maximum* *Setaria anceps* *Cynodon dactylon* *Cenchrus ciliaris*	*Desmodium uncinatum* *Stylosanthes guyanensis* *Pueraria phaseoloides* *Stylosanthes scabra*	Silk sorghum *Trypsacum laxum* *Pennisetum purpureum* *Setaria splendida* *Leucaena leucocephala* *Cajanus cajan* *Dolichos lablab*	(i) *Chloris gayana* *Panicum* spp., *Pueraria phaseoloides* *Stylosanthes* spp. (ii) Brachiaria, Setaria, Chloris *Stylosanthes* spp. *Desmodium uncinatum* *Sesbania sesban* (iii) Desmodium, *Cenchrus ciliaris*, Brachiaria *Cassia rotundifolia* (iv) *Chloris gayana*, *Cenchrus ciliaris*, *Stylosanthes* spp.

Paddocking

Subdivide the area into paddocks by fencing to allow rotational grazing.

Weeding

Some of the most important weeds to remove are *Sporobolus pyramidalis, Solanum incanum, Lantana camara, Phytolacca dodecandra* and *Capparis tomentosa*. Good shade trees should be left in place, especially indigenous trees, most of which support good grass growth underneath.

Oversowing

Often grasses, but mostly legumes, are oversown in natural pastures. Minimum tillage is recommended for good establishment. The area to be oversown should be hard grazed or slashed. Narrow strips (about 30 cm wide) or patches (about 60 cm^2 for large ones) should be dug up thoroughly in the grazing area or paddock. Some phosphate fertilizer should be spread on the strips or patches before planting. Grass or legume seed can then be broadcast on the strips or patches. Pretreatment of legume seed improves germination by breaking the hard seed coat. Different methods of legume-seed treatment are given in Table 12. Hot-water treatment is most practicable under farm conditions. Inoculation with rhizobium may be required for some species to ensure fast growth. The legume species currently in use in Uganda, except lucerne and clover, will nodulate with naturally occurring cowpea rhizobia.

Establishment of sown pastures

Where all the natural grass species have been overgrazed beyond recovery, or where weeds and bushes are dominant, it becomes necessary to establish new pastures. These could be permanent pastures where livestock are the dominant enterprise, or ley pastures where the pastures are part of a rotational system.

Seedbed preparation

A fine seedbed should be prepared for the purpose of providing rapid seed germination and seedling emergence and to eliminate or reduce competition from weeds. Avoid formation of a hard crust on the seedbed by preparing it before the heavy rains. On hillsides, all cultivation should be done on the contour to prevent soil erosion. Seedbed preparation can be improved if a cleaner crop such as sweet potatoes is planted beforehand.

Time of sowing

The most reliable time for sowing in bimodal-rainfall areas is during the short rains so that annual weeds are eliminated. In semi-arid areas what is needed is a coarse tilth that traps all rainfall and shields the seedlings from sun and wind.

Seed quality and treatment

Good-quality seed should be used to ensure proper establishment. Scarification of legume seed improves germination by breaking hard seed coats. Different methods of seed treatment are given in Table 12, but hot water is the most practicable under present conditions.

Inoculation with rhizobium ensures good legume establishment. Instructions for use of inoculants can be obtained from the Soil Science Department of the Faculty of Agriculture and Forestry, Makerere University.

Table 12. *Legume seed treatment*

Treatment method	Legume
No treatment required	Common stylo, lucerne, greenleaf desmodium, silverleaf desmodium, siratro, subterranean clover, white clover
Mechanical abrasion (scarification, de-podding, dehulling or polishing)	American joint vetch, fine-stem stylo, medics (annual), centro, puero, roundleaf cassia, glycine, shrubby stylo, Kenya white clover
Dry heat	Fine-stem stylo, carribaea stylo, roundleaf cassia, shrubby stylo
Hot water	Leucaena (80°C, 7–8 minutes; or 100°C, 7–8 minutes); centro and puero (boiling water equal to seed volume poured over the seeds and left for 30 minutes). After wet treatment, the seed should be spread out thinly and dried quickly

Seed rates

The rate of grass seed application adopted in Uganda is high because of poor seed quality and, often, poor seedbed preparation. Table 13 gives a pasture and fodder sowing guide for Uganda.

Method of sowing

Broadcasting is customary. Scattering small quantities of seed evenly over the land requires skill. A simple method of even sowing is achieved by dividing the area into equal portions (e.g. 4 equal areas) and likewise dividing the seed into equal portions (e.g. 4 equal portions). Then each portion of seed should be broadcast on to one of these areas. The seed should be covered with a very thin layer of soil using a bushy branch to brush the soil over the seed. Vegetative propagation is practised for those fodder crops for which it is difficult to obtain seed, such as Kikuyu grass and *Brachiaria* spp. Legumes like greenleaf desmodium and stylo have been established in a similar way. A fine seedbed is not absolutely necessary with vegetatively propagated pastures. Rooted splits of chosen species should be planted in cultivated land and the soil firmed down round them. If stolons without roots are to be used, they should have at least three active bud sites.

Table 13. *Sowing guide for grasses and legumes*

Species	Cultivar	Seeds/kg ('000s)	Seeding rate (kg/ha)	Soil fertility	Productivity	Min. rain-fall (mm)
Grasses	Elephant grass	Vegetative	Fair	Medium	850	
	Rhodes grass	3,000–4,000	10–15	Fair	High	650
	S. sphacelata cvs. Nandi, Kazungura, Narok, Solander	1,500	10–15	Fair	High	750
	B. decumbens (signal grass)	286	10–15	Fair	High	1,000
	Buffel grass	450	10–15	Fair	Medium	750
	Guinea grass	1,300	10–15	Medium	High	1,000
	Kikuyu grass	400	Vegetative	Medium	High	1,000
Legumes	Centro	40	3–4	Fair	Medium	850
	S. guianensis var. *guianensis* (common stylo) cv. Cook, Serere	400	2–4	Fair	Medium	850
	Lablab	4	10–30	Fair	High	650
	Glycine	150	2–4	Fair	High	
	Desmodium intortum cv. Greenleaf	600	1–2	Fair	High	750
	L. leucocephala cvs. Peru, Cunningham	22	4–6	Fair	High	750
	Pueraria	81	1–4	Fair	Medium	1,200
	Roundleaf cassia (*C. rotundifolia*) cv. Wynn	253	2–4	Fair		750
	Shrubby stylo (*S. scabra*) cv Seca	40	3–6	Fair	Medium	750
	Silverleaf desmodium *D. uncinatum*	210	1–3	Fair	High	900
	Siratro (*M. atropurpureum*) cv. Siratro	75	2–4	Fair	High	750

Management after sowing

Under optimum conditions, grass seeds germinate after two weeks and legumes in the third to fourth week. Weeds will also germinate along with these pasture seeds. If the weeds are very dense, they should be hand-weeded or slashed before flowering. Grazing or cutting should be avoided until plants are large enough (30-cm high) to withstand defoliation. Light grazing/cutting can be done 8 weeks after planting. Seedlings do not tolerate heavy shade; so 8–12 weeks after planting, light grazing (use calves for a few hours) or slashing should be done. The oversown species should then be allowed to flower and set seed before the area is put into the rotational grazing system. This may be after 3–6 months, depending on rainfall during the establishment period.

Weed control during and after establishment

Annual weeds are likely to infest pastures, and if not controlled lead to poor yield of the pasture. Some important control measures are:

- A well-prepared seedbed to begin with
- Slashing/light grazing the pasture when seedlings are about 30 cm high
- Hand-plucking the weeds; chemical control of weeds is possible if this is affordable.

7.5 Establishment of important fodder species

Fodder grasses

Elephant/Napier grass

Seedbed preparation

This is not as elaborate as for other pasture species established from seed. A weed-free seedbed is most suitable. Planting materials are disease-free whole canes, cuttings or rooted shoots. The most productive variety of elephant grass is KW16, which can be obtained at Namulonge, Kawanda or Kabanyolo Research Institutes.

Spacing

The canes (3–4 nodes) are spaced at about 1 m between rows and 0.6 m within rows. Close spacing is encouraged as this leads to high productivity both in a field and on contour structures.

Intercropping with legumes

Commonly, greenleaf desmodium and centro are sown into the rows at a rate of 1–2 kg per ha.

Fertilizer application

A manure and urine slurry should be applied in a systematic way to the fodder grass and worked well into the soil to avoid loss of nutrients. Well-fertilized grass is dark green.

Diseases

Two major diseases that attack elephant grass are stunting disease (viral) and white spot (fungal). The stunting disease inhibits growth, resulting in poor production. Fungal white spot disease has no significant effect on yield. To avoid both of these diseases, planting of disease-free canes is important.

Harvesting

Elephant grass should be allowed to attain a height of 1.2–1.5 m before being cut 2–5 cm from the ground. Usually it can be cut 10–16 weeks after first planting, and thereafter cutting intervals should be 8–12 weeks. One acre of well-established and managed elephant grass can support one cow and one calf.

Other fodder grasses

Guatemala grass and giant setaria are alternatives to elephant-grass fodder. They are grown and managed in similar ways. Giant setaria has been found to be very useful in stabilizing erosion-control structures in banana plantations, and in such situations yields are high. To restore fertility, even within soil bunds, slurry should be applied on the trench.

Fodder legumes

These include lablab and leguminous fodder trees such as leucaena, calliandra, gliricidia and sesbania.

Lablab

Seedbed preparation: A good seedbed, as for the ordinary beans, should be prepared. The lablab seed is relatively big.

Sowing rate and method: Lablab is sown at a rate of 5–7 kg seed per ha and the seed should be sown in the early rains using a spacing of 1 m between rows and 0.5 m within rows. Sowing depth can be 2–4 cm. It is not compatible with other grasses and legumes and so should be sown alone.

Weeding: Early establishment is slow and so weeding should be done to prevent competition.

Utilization: Lablab should be cut and mixed with grass before being carried to the animal. A sole diet of lablab may cause bloating. Only the leaves should be harvested, as heavy cutting of the stem will kill the plant. Lablab provides high-quality dry-season feed, and if properly managed can provide fodder for up to 12 months.

Leguminous fodder trees

Establishment, spacing, fertilizer requirement and weed control: see Chapter 6).

Harvesting: Harvesting any of these leguminous trees should be done when the plants are about 1.2 m high. A cutting length at about knee height is recommended, and cutting can be done every 8–12 weeks.

Productivity and animal production; The potential for producing fodder from leucaena, calliandra, gliricidia, sesbania and pigeon pea in Uganda is very good. Crude protein in the leaves is 20% or more, and this increases growth and milk production in animals that are fed grass and legume mixtures. Only one-third of the total volume of the feed should be legume fodder to avoid bloat problems.

7.6 Fodder conservation for dry-season feeding

The dry season in Uganda is 3–4 months long and this has a negative effect on the pastures which provide most of the feed for livestock. This leads to inadequate nutrition, both in quantity and quality, and so there is a need to conserve sufficient feed for livestock during this period.

High-quality plants for dry-season feed

Fodder grasses like elephant grass, Guatemala grass and giant setaria; fodder legumes like lablab and lucerne; and leguminous fodder trees like leucaena, gliricidia, calliandra and sesbania should be planted to create a 'fodder bank' for the dry season.

Cutting and preservation of hay

Hay is grass or a legume plant which has been purposely cut at the required time, dried and stored without further processing for feeding during the dry season, or to give balance to a ration which is very high in water, such as lush-growing fodder in the wet season.

Note: Half an acre of irrigated fodder, or 1 acre of rain-fed fodder, or, if on the contour, a 1-m wide strip 4,000 m long planted with fodder, will provide sufficient food for a mature cow or 4 goats throughout the year. The best way of utilizing these fodder crops is by cutting and carrying to the animals.

Quality of grass and legume hay

Hay can be made from most types of grass and legume, singly or in combination. The right stage for cutting is just before flowering when the nutrient content is highest. During the process of drying, more than 25% of nutrients are lost. Operations should be planned so that the hay from any given area can be cut, handled and stacked in less than 2 days.

Cutting

Farmers traditionally use a slasher or sickle. The field should be cut across in one direction. The cut grass should then be left to dry in the sun for at least 4 hours. After one side is dried, the hay should be turned over and left for another 4 hours. It can then be piled in a heap.

Stacking or baling

After drying, hay should be stored indoors or where least contamination will occur. If termites are a problem in the area, clear and destroy termite mounds within a radius of at least 100 m around the stack and watch out for developing termite colonies and destroy them. If this does not solve the problem, build a low platform with legs immersed in used motor oil and stack the hay on the platform. Baling hay saves storage space and avoids wastage during feeding. A method of hay making using an inexpensive hand-baling box made of wood has been developed in Kenya (Tessema et al. 1987) for small-scale dairy farms and could be adopted in Uganda. This method requires three men to cut and load the baler, and it is possible to make 10 bales of hay (15 kg each) per day.

Making silage

Silage is the product that results when grass or other green forage is enclosed in an airtight container. The anaerobic conditions created cause the fodder to ferment, thus preserving most of the nutrients. Good-quality silage is obtained if it is started from good-quality fodder. Grasses and legumes should be cut when the flowering stage is just beginning or, if maize or sorghum are to be used, when the grains are still soft and milky.

Type of silo

The best kinds of silo for use in Uganda are the silage pit (trench) or a bag silo, depending on the size of farm. The pit should be reasonably small so that it is easy to compress the fodder during the process of filling. The pit should be about 1.25 m wide at the top and about 1 m at the bottom with a depth of 2.5 m. The floor and sides should be covered with banana leaves or plastic to reduce spoilage due to soil and soil moisture.

Preparation of material and filling of the silo

- Cut the fodder to be ensiled.
- Chop the fodder into pieces about 3 cm long to facilitate compaction and exclusion of air. Filling the trench or bag silo should take as short a time as possible.
- Compress the chopped fodder as it is being put into the silo. It is important to exclude as much air as possible. Tight packing can be obtained by having people jump up and down on the fodder until it will sink no more. A pestle can be used to ensure compaction in a bag silo.
- If available, molasses should be mixed with the fodder while filling the trench to encourage rapid fermentation and increase the energy content of the silage. If molasses is not available, powdered cassava can be sprinkled on at the rate of 0.5 kg for each 10-kg layer.

When the silo or container is full and the material in it can be compressed no further, it should be left to settle overnight. A final compressing is done and the silo then closed by covering with a sheet of plastic, or banana leaves or stems. Finally, it is covered over with a layer of soil.

Quality of silage

The silage will be ready after 1–2 months, but can remain untouched for a much longer period. When the trench is opened, the silage should be yellowish green to light brown in colour and should have a sharp but pleasant smell. Properly made silage retains all the original nutrients and is slightly higher in feed value than the same fodder dried as hay.

Feeding silage

When silage is first offered to livestock, they may refuse to eat it. This is because it is strange, but once the animals are used to it they will love it. It should first be mixed with familiar feeds and offered regularly in small quantities until the animals do get used to it.

Note:

- Any palatable green material can be ensiled
- You can make silage all year round when you have 2 or 3 days of dry weather
- The trench should be closed after each day's silage is removed; keep rainwater out of the pit.

Field residues as forage

During the dry season, anything brought from the field is potential livestock feed. The following field residues can be important feed for animals (in order of importance and feed value): sweet-potato vines; bean, groundnut and other legume haulms; avocado, guava and mulberry leaves; banana and potato peelings; banana pseudostems and leaves. To maintain productivity of livestock and improve the quality of these feeds during the dry season, supplementary concentrates should be provided. A farmer who is self-reliant in the production of high-quality fodder of various types will need less commercial high-cost concentrates and will produce milk/meat at a higher profit.

7.7 Common livestock ailments

Common ailments and conditions that a good livestock farmer should recognize and prevent will be described in this section. For serious conditions, consult the veterinarian.

The healthy animal

A healthy animal is well fleshed. The ribs may just be defined but not standing out starkly under the skin. The anterior points of the pelvis should be rounded, not angular or sharp. The hair of the coat should lie flat and have a good shine to it. The animal should be calm but able to react to stimuli such as noise or rousing, able to get up, walk, and breathe quietly and effortlessly, to move without pain and to mingle easily with other animals. The animal should be eating and ruminating normally without obvious wounds or rashes. The ears should be alert, the nose moist with small droplets. The eyes should be bright and the membranes around the eye a healthy pink colour.

Table 14. *Common cattle diseases requiring regular immunizations*

Disease	Class and age	Frequency of immunization
Foot and mouth disease	All cattle	Every 6 months
Haemorrhagic septicaemia	All cattle	Every 6 months
Blackquarter	All cattle	Once a year
Anthrax	All cattle	Once a year
Brucellosis	Calves at 6 months	Once, then again at 2 years
Lumpy skin disease	All cattle and calves	Once a year
Rinderpest	All cattle	Once at 6 months, again at maturity
Trypanosomiasis	All cattle	Depending on the area

Note: These are infectious diseases which can readily pass from cow to cow, and some of which are also dangerous to man, so extreme care is required to prevent them from spreading.

The vaccination regime

Common diseases can be prevented, and it is worth the expense of vaccinating against such diseases. The local livestock officer should be consulted on the availability of vaccines and the regime to be followed because this varies from place to place depending on the diseases that are common.

7.8 Breed improvement

Upgrading the herd

Milk or beef production can be increased considerably and profitably by breeding with good bulls or using the artificial insemination (AI) service. The choice between breeding using a bull or AI should be determined by availability of the AI service. It is imperative that upgrading be done in order to increase productivity. On beef ranches, Boran bulls can be crossed with indigenous cattle to improve birthweight and growth-rate performance of the offspring. On the other hand, using exotic Friesian and Charolais bulls on indigenous cattle improves liveweight gains and mature weight, although the offspring are more susceptible to stress. Milk production is improved. Currently, the Artificial Breeding Centres (ABCs) are functional in many Districts of the country and the local District Veterinary Office should be consulted for details.

Artificial insemination

Artificial insemination (AI) services offer an economical method of obtaining improved stock. Frozen semen from selected high-quality bulls is transferred to female cattle by artificial insemination. Advantages of artificial insemination are:

- Semen from very expensive pure-bred bulls is made affordable to farmers
- It eliminates the cost and inconvenience of keeping a bull
- It avoids transmission of many contagious diseases.

Heat detection

The appropriate time for service, i.e. the oestrus period, is very important for successful AI. It is important to detect this period and achieve conception every time to avoid long unproductive lactation periods and long calving intervals. The average length of oestrus is 21 days, and so this should be strictly observed.

The following signs show that the cow is on heat and so ready for service:

- Temporary drop in milk yield
- Restlessness and reluctance to feed
- Bellowing
- Excites other cows to mount, and stands to be mounted
- Swollen and reddened vulva lips
- A clear, thin, mucous discharge hanging from the vulva or adhering to the tail.

Time of service

Oestrus should recur every 18–22 days until the animal is served. The heat period lasts 6–30 hours, during which time serving should be done. Causes of low conception rates are failure to detect the heat period, or poor health of the animals. Poor nutrition is also an important factor.

Care while using a bull

The bull selected for breeding should have no obvious defects in the testicles, penis, legs or other general features. He should also be disease free. A bull of the same family line (father, brother, son, etc.) should not be used in the herd. Consult a local Veterinary Officer to find out whether the bull is a suitable one to use.

7.9 Dairy goats

Dairy goats have only recently been introduced in Uganda and are currently kept under zero-grazing systems in hilly parts of the country where land scarcity limits the area available for fodder growing. In high-potential areas, there is an excellent case for increasing the number of dairy goats. Small areas of waste and steep ground can be utilized and crop residues put to good use. Five or six goats can be kept on the same amount of feed and grazing as required for one cow. But dairy goats require as much careful attention as dairy cows.

Improved goat breeds

Two main breeds are currently used. The first is the tropical Anglo-Nubian, which are mainly red-brown and white in colour and have long legs and floppy ears. The female weighs 60–75 kg and will produce 1–2 litres of milk a day. The second type is the temperate Toggenburg, which is mainly white and fawn with cream stripes and has erect forward-pointing ears. The female weighs 40–50 kg and is able to give 2–3 litres of milk per day.

Management of dairy goats

Breeding

Goats can produce 2 kids a year or 3 every two years. Twinning occurs, but is usually less than 10% of births. Mating may take place when the female is 5–6 months old, but it should be prevented until she is 12–18 months old. Unwanted male goats should be castrated before the age of 4 months.

Grazing

Under intensive husbandry, dairy goats should be provided with fodder as already discussed for dairy cattle. Browse must be provided for dairy goats, with concentrates for lactating animals if possible. Water should be provided *ad lib*, preferably outside the pen to prevent fouling. Milk goats require calcium, so calcium-rich feeds such as lablab, calliandra and sesbania should be provided. Other minerals can be provided in the form of mineral licks.

Zero-grazing

Goats can be tethered on a good strong rope and moved twice a day to a fresh piece of ground or bush. Good-quality hay must be supplied because goats do not do well on large amounts of lush grass. Where concentrates are not readily available, if possible, farmers should make up rations consisting of 70% grain, 15% cottonseed cake and 15% meat-and-bone meal. The following could also form a suitable ration: maize milling wastes, dried brewers' grain, ground-up beans (or any other grain legume for providing protein).

Housing

At higher altitudes, a warm but well-ventilated house is required. This should consist of several individual pens, with a floor of rammed earth or concrete allowing for free drainage. There should be feed racks for hay, feed troughs, a mineral lick and water troughs. Each goat requires approximately 2.25 m^2 of floor space.

Care of hooves

In zero-grazing systems, the animals' hooves tend to grow too long and this may damage the feet. Inspection should be carried out every few months and trimming done with a sharp knife. In addition, at least part of the floor of the pen should consist of a layer of stones or concrete slabs so that the animals' hooves are worn down by walking on them.

Diseases

The following are notifiable diseases of goats:

- Anthrax
- Foot-and-mouth disease
- Heartwater
- Rabies
- Trypanosomiasis
- Tuberculosis.

8. Fish farming

8.1 Introduction

Fish farming is a part of aquaculture, which also includes the growing of animals and plants in fresh, brackish or marine water. Fish farming is the rearing of fish under controlled conditions in order to attain yields higher than those normally obtainable under natural conditions.

8.2 Advantages and importance of fish farming

The main advantages of aquaculture over conventional fishing are:
- Environmental conditions can be controlled
- Fish farming can be done on land that is not suitable for cultivation
- It is easier to catch the cultured fish than wild ones
- Farmers are assured of a certain quantity and quality of produce
- Fish farming can become a major income-generating activity in integrated rural development schemes
- Fish farming can directly or indirectly improve rural nutrition and employment and increase rural incomes.

8.3 Major objectives of fish farming

- To provide a cheap protein source since meat is becoming more expensive.
- To provide a source of income for farmers, especially in the resource-poor rural areas.
- To provide employment, especially in rural communities.
- To improve both the quality and quantity of fish produced through proper management techniques.
- To preserve fish species which are threatened by over-exploitation.
- To provide sustainable use of wetlands.

8.4 Fish-farming methods

Pond fish farming is the only kind of fish farming that is practised in Uganda. The most important factor in this technique is the proper siting and digging of the pond. The farmer must also apply fertilizers, stock at the correct rate, follow correct feeding regimes, sample the fish at regular intervals and harvest and market at the right time. When in doubt, the farmer should contact the nearest extension worker.

Site selection

Before deciding to build a pond, the proposed site must be studied and a number of factors considered:

- Avoid areas with trees, rocks or pure sand as they will cause many problems during pond construction
- Ponds should not be dug in places where floods occur during the rainy season as the fish will be washed away
- Ponds should be constructed close to the water source, e.g. river, lake, swamp, groundwater, etc.
- It should be possible to fill or empty the pond by gravity (no pumping)
- The water supply should be reliable and constant all year round
- The soil should be loamy clay or clay, not sandy, to avoid seepage
- The pond needs constant attention so should not be too far away from the farmer's home.

Two tests are carried out to determine the suitability of a site for fish culture:

- Groundwater test
- A soil test for permeability.

Types of ponds

Depending on the site, one of the following pond types can be constructed:

- Embankment pond
- Excavated pond
- Partially excavated pond with low walls.

Of these three, partially excavated ponds are recommended as being cheaper for rural fish farmers since they do not need pumping for filling or draining.

Pond construction

The planned pond should not be too big as this will be difficult to manage later. A rectangular pond between 200 m^2 and 2,000 m^2 in area is suitable. A rectangular pond is easy to manage, reduces the cost of maintaining the walls and makes it easier to harvest the fish.

The following procedure is used:

For a 10 x 20 m pond, the wall should have a base of 3.25 m. Then a rectangle of (3.25 + 10 + 3.25) x (3.25 + 20 + 3.25) = 16.5 x 26.5 m must be marked out using sticks and string so that the outside of the walls can be clearly seen. Topsoil should not be used for wall construction as it contains leaves, stones and roots. Remove 15–20 cm of the topsoil from the surface in the marked-out area and pile it on one side. Later the topsoil can be used to cover the clay walls.

Using new sticks and a second string, mark another 10 x 20 m rectangle within the first one, leaving a distance of 3.25 m between the two strings. Plan the location for the water inlet and also for the outlet (the monk). If a monk is to be constructed, dig a trench 65–75-cm deep for the outlet.

When building the walls, take soil from inside the rectangle. Dig about 65 cm deep in order to have enough soil (130 m^3) to build the walls. The pond bottom should slope towards the outlet on a gradient of 2–3 in 1,000. Wet the walls and compact them until the soil is firm. *Ensure the correct depth: 145 cm near the inlet and 150 cm at the outlet.*

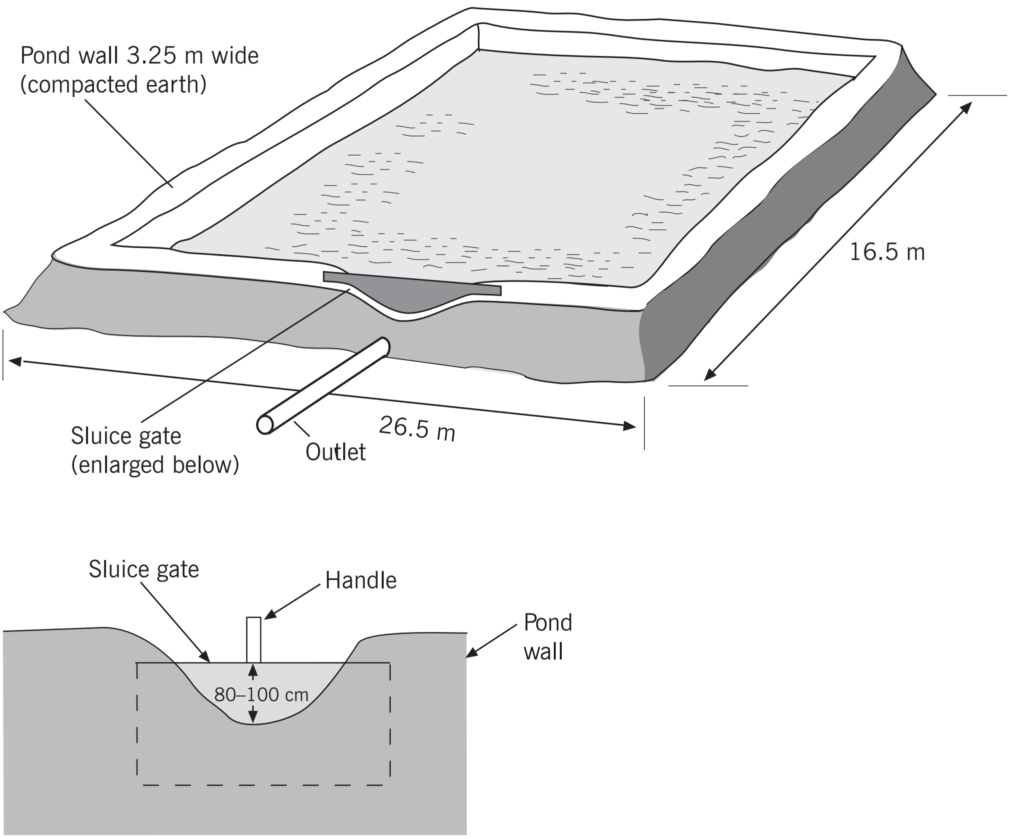


Figure 29. *Dimensions for a fish pond.*

Make a wooden or concrete sluice in the water-supply channel so that the rate of water inflow can be regulated. The sluice should be screened to prevent wild fish, tree branches and leaves from entering the pond. A 1-cm screen mesh is often suitable.

- Start filling the pond until a water level of 80–100 cm is reached. Regulate the water level using the sluice gate (see Figure 29).
- Stabilize the banks of the pond by planting grass such as *Paspalum* sp., Rhodes grass, *Chloris gayana* or star grass. Do not use plants with long roots or trees as they will weaken the walls and cause leakages.
- If several ponds are to be built, it is best to construct them in parallel and not in series so that each pond can be independently supplied and harvested, and also to avoid affecting lower ponds from any polluted discharge or introduction of disease from upstream.

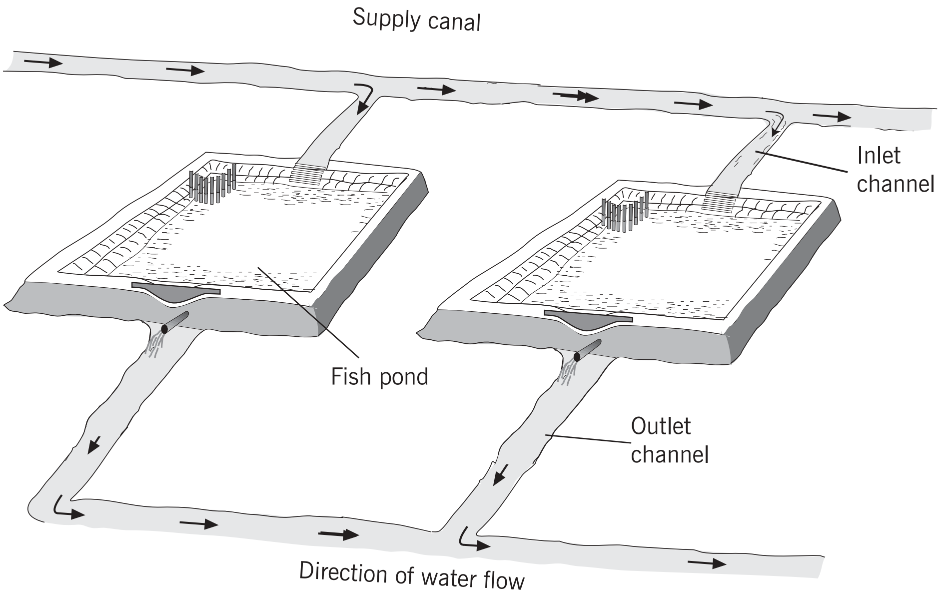


Figure 30. *Typical layout for a series of fish ponds.*

Liming and fertilization of the pond

Liming newly excavated ponds

Liming of newly excavated ponds should be carried out to ensure the water is at a suitable pH. The appropriate amount of agricultural lime to apply will depend on the initial pH. Then the pond is filled with water and left for about a week during which the pH will have stabilized to 6.5–8.0. Where lime is not available, wood ash can be used.

Fertilizing new ponds

After liming, the pond should be fertilized to increase its natural food production. Fertilization can be done by adding organic or inorganic fertilizer, or both. Organic fertilizer (manure) can be added to the water at a rate of 6,000–7,000 kg per hectare per year. This means 16–20 kg per day. Organic manure can be obtained from cattle, pigs, goats, sheep, and chicken droppings.

Cultured fish species and feeding regimes

Presently there are two main types of fish that are widely accepted for culture in Uganda:

- Tilapia (*Tilapia* spp.)
- The common or mirror carp (*Cyprinus carpic*).

Stocking rate

Tilapia fry can safely be stocked at the rate of 2 fish per m^2, thus obtaining a population of 20,000 fish per hectare, while mirror carp can be stocked at 10,000 fish per hectare. Tilapia will grow to table size (400–600 g) in 6–9 months with supplemental feed being added. Mirror carp will weigh 750–1,000 g in 9–12 months.

Brood stock

In the case of mirror carp, the two sexes should first be fattened in preparation for breeding. The two sexes are stocked separately at a very low density of only 2,000 fish per hectare (i.e. 1 fish for every 5 m^2). This is usually unnecessary for tilapia. However, in tilapia selection of healthy well-formed males and females is very important. Breeding males and females are then put into one pond at a ratio of 2 males to 1 female to ensure fair and even fertilization of the eggs.

Feeding

Fish fry (newly hatched) are fed at a rate of 10%–15% of total bodyweight stocked in the pond. Fingerlings are fed 5%–10% of bodyweight, and adult fish 3%–5% of bodyweight twice a day.

Types of supplemental feed

A variety of fish feeds are available locally for the different fish species:

- *Tilapia niloticus* are fed on maize bran, maize grain, fishmeal, soya-bean meal and rice bran
- *Tilapia zilli* are fed on plant material such as leaves of potatoes, cassava and cocoyam and banana peels
- Mirror carp are fed on maize bran, rice bran, fishmeal, fish by-products and animal waste.

Feeding is generally done twice a day, at 7.00 a.m. and 5.00 p.m., and at the same location in the pond each time.

Sampling

Fish should be sampled at regular intervals to check on mortality, growth and general status. Sampling should be carried out with the right type of net. Recommended mesh sizes are as follows:

- Fry—seine net of 5-mm mesh size
- Fingerlings—seine net of 1-cm mesh size
- Adults—seine net of 2-cm mesh size.

Pond care and management

- Monitor the behaviour of the fish or fry in the pond at least once a day in the morning. Fish should be actively searching for food on the pond bottom or at the surface of the water.
- Check the transparency (clearness) of the pond water. A green colour is a sign of good natural food production. If the pond water is too dark, however, this indicates the presence of too many plankton (the microscopic organisms which are the fishes' natural food) and resulting depletion of oxygen in the water. When the oxygen content is too low, the fish remain on the surface of the water. The solution is to increase the rate of water flow in and out of the pond and to suspend fertilization of the pond until the fish resume normal swimming.
- Always clean the inlet and outlet screens.
- Check the walls of the pond; weak points and leaks should be repaired immediately.
- Keep the grass around the pond banks and dikes short to keep away predators, e.g. snakes.
- Remove any submerged water weeds in the pond as they make harvesting fish difficult. They also compete with plankton for nutrients.

Fish handling and transportation

Fish sampling and harvesting should be done in cool weather, preferably in the morning when temperatures are low. Fish should also be transported to market when it is cool.

Relocation of fish to another pond should also be done during the morning. On arrival, fish should be released slowly in order to avoid sudden temperature change and shock. The mouth of the bag in which they have been carried is opened and placed in the water of the new pond and the fish allowed to find their way slowly into the new environment.

Fish diseases and treatment

In the water environment, pathogens are easily transmitted from fish to fish via gills and skin. The most vulnerable groups are the fry and fingerlings. Infective agents in the water can be viruses, bacteria and multicelled parasites. The causes of infections can be poor water quality and poor feeding habits. Rough handling can also cause stress to the fish. Diseased fish are recognized by decreased appetite, sluggish swimming, staying in a vertical position in the water, brown spots, protruding eyes or mutilated fins.

Table 15. *Causes and signs of common fish diseases*

Cause of disease	Sign of infection
Bacterial diseases	Fish stay in a vertical position, sluggish swimming, white spots on skin near the mouth and fins
Fungal diseases	Cotton-like fungal or ectoparasitic growths seen on skin, mouth and fins (may be precipitated by rough handling)
Parasitic diseases	Skin is covered by greyish-white mucoid fluid
Stunting	The situation where fish do not grow to the expected size and weight. The solution is to lower population density by cropping or use of natural predators

Treatment of fish diseases can be carried out in two ways:

- External treatment by immersion in medicated water
- Systemic treatment via the diet (drugs being incorporated into the fish food).

In most cases, external treatment involves immersion of the affected fish in a chemical solution. This can be carried out at various times depending on infection intensity:

- Bathe the fish for 30–60 minutes
- Prolonged immersion: this takes up to 12 hours
- Dips: fish are dipped in a strong solution for 1–5 minutes
- Flushes: a small volume of concentrated chemical is added to the inflow and diluted through the pond by flowing water.

9. Agricultural extension

9.1 Introduction

Extension is the non-formal two-way educational process where local people and extension workers learn from each other with the aim of improving the livelihood of the people. Extension can also be defined as a process of integrating local and scientific knowledge, attitudes and skills to determine what is needed, how it can be done, what local co-operation and resources can be mobilized and what additional assistance is available, or may be necessary, to overcome particular obstacles (Sim and Hilmi 1987).

The emphasis is on the farmer's own contribution in the identification of investment and production options, the associated constraints and available solutions.

9.2 Role of an extension agent

The role of an extension agent is to motivate and educate farmers and to disseminate information that will help solve production problems that are identified by farmers. It includes the following:

- Helping farmers identify, express and communicate their perceived problems and needs.
- Assisting rural communities to come up with their own solutions to the problems.
- Creating awareness and informing the community about new technologies and opportunities for addressing the identified problems. Such information can be about production options and approaches, marketing possibilities, sources of inputs, access to capital and other credit facilities, and how to improve business.
- Assisting and guiding the community in finding ways by which natural, human and institutional resources in the community can be mobilized and organized to promote rural development.

9.3 Extension approaches or methods

Common extension methods used in Uganda are:
- The individual approach
- The group approach
- Mass media (radio, newspapers and television).

Other extension methods used include targeting young people in schools.

The individual approach

The individual approach offers a better opportunity for intensive farmer–extension worker interaction. This approach helps:
- Develop an individual land-use plan for farmers (local-level planning)
- Guide motivated farmers in development of new technologies
- Carry out on-farm demonstrations on new technologies or to show the benefits of the recommended technologies
- Approach individuals within the group or community who have different goals and interests
- Solve specific problems pertaining to individual farmers, e.g. laying out conservation structures, selection of sites for woodlots and pastures
- Clarify messages which had not been fully understood by farmers during various meetings
- Provide guidance during the implementation phase
- Monitor and evaluate the impact of technologies and other recommended practices.

Disadvantages of the individual approach

- It is expensive in terms of logistical and time requirements.
- It is not possible to reach many people with a limited number of extension staff.
- The area that can be covered and the number of farmers visited is small as farmers are approached individually.

The group approach

This involves working or interacting with groups of farmers or the whole community through:
- Visits to farmers' groups in rotation
- Carrying out field demonstrations at the homes of contact farmers
- Making study visits or exchange visits by farmers within or outside their area of operation
- Agricultural shows and local meetings.

For the group approach to be effective, there should be contact persons or opinion leaders who may be used to mobilize the community or group members. The mobilization can be in places where the community members commonly meet, such as market places, places of worship, drinking places, or even at funeral gatherings.

The group approach is appropriate for:

- Discussing matters related to the whole community
- Making contacts with common-interest groups while discussing matters of concern with them
- Making personal contact with many farmers at the same time for the purpose of conveying urgent messages or creating general public awareness on new events and technologies
- Exposing community members to new ideas during study visits, excursions and agricultural shows
- Enabling community members to exchange ideas and experiences among themselves or with visitors
- Encouraging community members to take collective decisions in tackling problems affecting the community as a whole, for example, in the control of bush fires, construction of communal dams, and marketing of produce.

Disadvantages of the group approach

- Underprivileged members of the community may not be attended to adequately. Such members include women and youth who have no land-ownership rights, and also poor people who may lack the necessary resources such as land and cash.
- It does not satisfactorily address specific problems of individual farmers.
- Influential members of the community may dominate discussions, especially when they are rich or members of the political elite.
- It is difficult to reach a common understanding where members have different interests or where the community is highly stratified (for example, rich vs. poor; those with plenty of land vs. the landless); where the culture discriminates on resource ownership, and also where the community is unorganized. In fact, few matters that can be discussed will be relevant to the whole community.

Common-interest groups

The idea of working with groups was conceived to overcome some of the problems associated with the individual approach. A common-interest group (CIG) is a group of individuals who share common problems and aspirations.

In general, a CIG should have the following features:

- It is a supportive framework for the promotion of individual activities. It can be used to overcome labour and financial constraints during implementation.

- It can be formal (registered), or remain informal.
- It may last for a short time, be disbanded once the objective is achieved (such as the USCAPP groups for construction of water conservation trenches in banana farms), or it can last much longer if the group is dynamic and is involved in income-generating activities.

Benefits of working with organized groups

Working with CIGs offers an opportunity for effective participatory planning, which is a better alternative to the conventional 'top-down' extension process. Working with organized groups:

- Provides an opportunity for the local community to analyse local problems and develop appropriate solutions together with extension agents
- Encourages the exploitation of local knowledge as well as external expertise (technical solutions) for assessing local needs, problems, potentials and opportunities through the active participation of the intended beneficiaries
- Promotes communication and extension of appropriate practices from farmer to farmer and community to community
- Joint planning gives the group members the opportunity to develop their own land-management plans, thereby encouraging active participation
- Strengthens and encourages leadership potential thereby stimulating the original groups to function as resource persons and alternative extension workers within the community
- Creates the opportunity for joint monitoring and evaluation.

Formation of common-interest groups

In a community where no groups exist specifically to deal with land husbandry (soil conservation), it is inadvisable to try to form them too hastily before the community is properly sensitized and they have seen the need. USCAPP experience has proved that when farmers have seen the benefits of a specific technology, they naturally become motivated to form groups for implementing it. In such a situation, it is better to initiate group formation gradually, starting with contact farmers as a nucleus and using the contact farmers to persuade their neighbours to come together. Group formation can then be promoted through joint meetings and training of the contact farmers and the neighbouring farmers. Only interested farmers join the contact farmer. At the beginning, the group should be small so as to allow proper supervision and training.

Where there are existing groups in the community (but for a different purpose), the concept of land management should be introduced to the members step by step, starting with those activities which complement the groups' original objective. Such groups should be supported to undertake improved land-management activities as one of the major eventual targets.

Benefits of common-interest groups

- Members encourage each other and support one another in planning and implementation.
- Certain land-husbandry practices require collective effort and can best be achieved when farmers pool their resources for carrying out various activities.
- Provide an opportunity for effective and efficient training since the training needs are demand driven.
- Easier to mobilize resources for purchase and transport of inputs and for organizing better marketing.
- The group is more confident in requesting assistance from the local administration and government departments, and in demanding other services to which they are entitled.

Local-level land-use planning

After general mobilization of the community (for instance, through a PRA exercise—see Section 9.5, below), individual farmers who have shown an interest should be helped to translate the agreed plans into action on their own farms. Local-level land-use planning involves collection of data and other necessary information about the farmer, his land holding, analysis of the information and making proposed changes together with the farmer.

Collection of information for planning

The collection of data on individual homesteads should, if possible, be carried out by multidisciplinary teams so that the final plan is holistic and caters for all the enterprises that the farmer is undertaking or intends to undertake in the future. The procedure should start with a walk round the farm (farm reconnaissance), together with farmer(s) and members of the family. During the farm walk, the extension agents should note the existing enterprises (crops, livestock, trees and fodder), general landscape, soil types, average slope and land-degradation problems. After the farm walk, the farmer and the team should stand in a place where it is possible to have a general view of the farm. A sketch map of the farm is then drawn showing the location of all the major features (homestead, crops, woodlots, paths and grazing areas).

Development of the plan

After drawing the map, the extension agents and the farmer should analyse the information they have collected in open discussion. It is important to identify major land-management constraints taking into account the particular farmer's socio-economic situation and present land-management system. The farmer should also indicate his/her future plans on the use of the land.

After proper analysis of the problems, possible solutions are suggested in line with the farmer's existing situation (his knowledge, socio-cultural and socio-economic conditions). Once the suggestions are agreed by the farmer, a second sketch map is drawn showing the proposed plan. This map should indicate where the enterprises will be located on the farm, the type of conservation activities and where they should be located. In the case of annual crops, the plan should indicate how the crops will be rotated. If the farmer wants to have permanent pasture, the plan should also indicate methods of improvement and the pattern of rotational grazing.

The farmer should be given a copy of the proposed development plan, which is necessary for follow-up and monitoring. The farmer's copy provides the opportunity for continuity in the proposed work even if the area extension agent is transferred later on. It is also important because it can prevent possible conflict of interest among extension agents of different disciplines. Where possible, a general work plan for the farm should also be indicated so as to guide the farmer (see Thomas 1997, page 189).

Mass extension methods

These methods involve the use of radio, newspapers, posters, drama, television and films/slide shows.

Mass extension is suitable in the following situations:

- If the objective is to create awareness and wide publicity on urgent matters
- Where it is not possible to reach many people due to remoteness of an area.

Disadvantages of mass extension methods

- Only a limited amount of information can be transmitted at one time.
- It is difficult to evaluate the impact of the information (lack of immediate feedback).
- Not effective where most members of the community are either illiterate or too poor to afford radio or television sets, and the production and distribution of printed materials is costly.

It should be noted that none of the methods mentioned can be singled out as being the best. The choice of the best method/approach depends on such factors as:

- Level of community organization
- Type and purpose of extension message
- Availability of resources at the extension agent's disposal
- Area to be covered by the extension agent.

9.4 Extension management and delivery systems

The main extension management and delivery systems are:

- Training and visits (T&V)
- Unified agricultural extension.

Training and visits (T&V)

The training and visits system is built on individual and group approaches. In this system, an extension agent receives training on relevant issues that need to be communicated to farmers. The agent then passes the messages to a contact farmer who, in turn, is expected to pass the same messages to the farmers in his or her contact group. The important features of the T&V system are:

- A rigid time schedule which is formulated by all the agents and is strictly adhered to
- Regular training of extension workers, e.g. every fortnight
- Regular field visits by extension staff
- Each extension worker has a specific area of coverage and number of farmers to cover
- A relationship with researchers is formalized to ensure regular contacts and flow of research information
- Constant back-up and linkages between the farmers, extension agents and researchers for development of appropriate extension packages
- Assumes gradual spreading of the benefits of the knowledge gained by the contact farmers to the neighbours (contact-group members).

Benefits of the T&V system

- Ensures regular supervision through the rigid work time schedule.
- Ensures proper monitoring and evaluation through constant field visits.
- Ensures regular flow of new or improved technologies through the formalized linkage with research.

Main drawbacks of the T&V system

- It requires a lot of resources in terms of staff, logistics and subsistence.
- Concentrates messages and advice on the prepared packages, which may not cover all the interests of the farmers involved or solve urgent current problems outside the schedule.

Unified agricultural extension programme (AEP)

This programme is based on the T&V methodology, and is the system currently being implemented by the Ministry of Agriculture, Animal Industry and Fisheries in Uganda. Specific objectives of AEP are to:

- Improve efficiency in the delivery of extension services
- Build up the capacity and skills of extension agents and farmers
- Promote adoption of improved technology by farmers.

Key features of AEP

- Planning is based on the farming-systems approach, involving farmers, extension workers and researchers.
- A field extension worker delivers extension services on crops, livestock, fisheries and natural-resource management to ensure efficient utilization of scarce manpower.
- There is a single line of command from grassroots extension workers to District extension co-ordinator and/or production co-ordinator.
- There is systematic and regular training (monthly training workshops, farmer training and in-service training).
- There are regular and planned work schedules allowing verification.
- Efforts are concentrated on selected enterprises, messages and impact points.
- The focus is on farmers' groups with specific attention on women and youth.
- Linkages between farmers, extension, research and marketing are strengthened.
- Collaboration with NGOs, universities, schools and other relevant institutions is encouraged.
- There is scientific monitoring and evaluation of implementation of the programme.

Mode of operation

In AEP, a single field extension worker (FEW) provides extension services for problem solving and technology transfer for all the relevant subject areas. FEWs are supported technically by subject-matter specialists and county extension workers through regular visits.

9.5 Participatory Rural Appraisal (PRA)

PRA is a multidisciplinary and participatory tool through which local people undertake their own appraisal, analysis, action and monitoring and evaluation.

Key features of PRA are:

- It is multidisciplinary, drawing ideas and resources from a variety of disciplines
- It is interactive and promotes active participation by local people and specialists in all decisions and activities
- It is quick and relatively cost effective in encouraging dialogue, joint analysis and learning
- It is simple, easy, non-statistical and places emphasis on descriptive methods and encouraging local (traditional) methods of analysis
- It provides an opportunity for sharing of knowledge and narrowing the knowledge gap between specialists and farmers and among specialists, thereby creating an open environment for learning

- It promotes participatory research, thereby enabling farmers to design, carry out and evaluate their own experiences
- Conventional roles are reversed with the local people becoming experts on the local situation, enabling outsiders to learn about local realities, needs and priorities.

The main features of the PRA village planning workshop are the following:

- It should be participatory; all villagers should be invited
- It should be democratic; the voices of all interested people should be heard (including the underprivileged)
- All issues in the village should be covered; it must be holistic
- The planning must be flexible
- It must be interdisciplinary or multisectoral (chiefs, extension agents, livestock, forestry, water, community development opinion leaders)
- It should lead to the promotion of self-help/self-reliance
- Farmers should take the lead in the planning
- Staff listen to farmers to learn from them and facilitate the process
- It is an evolutionary process without a blueprint, but rather developed by the practitioners as they go along
- It releases the silent intellectual, physical, political and productive potential of the people
- It helps narrow the knowledge gap and gives the opportunity for a two-way learning process.

The following are the possible steps in carrying out a PRA exercise.

Step 1: Preparation

Field reconnaissance

- Identification of the area to be covered, i.e. County, Parish, cell, etc.
- Identification of people to be involved, i.e. multidisciplinary team and others.
- Obtaining a visual overview of the area's physical environment (topography, soil type, vegetation, drainage and land-use patterns).
- Obtaining information from secondary sources about the area to be covered. Such information could be written reports, literature about natural resources, land use, health, nutrition, soils, market facilities and prices.

Making practical arrangements

- Informing local authorities and opinion leaders in the identified areas.
- Selecting appropriate venues for meetings and discussions.
- Training of facilitators on the PRA approach and communication skills.

Step 2: Combining local and expert knowledge

Group discussions and meetings

These aim to:

- Cross-check the information obtained from field reconnaissance
- Obtain detailed information about the area from the people.

The information should include the following:

- Socio-economic issues, e.g. land tenure, farm size, land-use pattern
- Community organizations
- Labour availability
- Past and current land-management practices and experiences
- Livestock types and management systems
- Crop-growing calendar
- Water resources
- Vegetation, trees, and grazing land
- Soil-degradation problems and conservation measures practised.

The group discussion can either be through focus (homogenous) groups, such as certain age groups, women's groups and village heads who can give in-depth information about particular issues, or through interactive discussion which involves subdividing the villagers into separate groups but discussing the same issues at separate times. It is important to ensure that all the group members give their views from the perspective of their own needs, priorities and concerns.

Step 3: Analysis

This involves meeting knowledgeable people and representatives of the groups (women, youth, the landless) and others, to identify the major issues and methods of addressing them.

Brainstorming for farmers to express their opinions and ideas

- Make a master list of all problems and potentials, including all the theoretically possible solutions
- Try to understand the causes of the main problems
- Selection of priority issues:
  - Choose the most important issues affecting all the community members
  - Separate the different issues that can be addressed by the individual approach or by group action
  - Discuss the details of how selected solutions could be further developed.
- Bring up important policy issues that can affect the implementation process.

Step 4: Planning

Having identified the major problems, causes and linkages, village meetings should be held to agree on the appropriate recommendations and methodologies for implementing the measures:

- Present the prepared master list and get the views of the community members
- With the villagers rule out those solutions that are impractical
- Select solutions that are practical and can be implemented
- List possible activities for tackling each priority issue
- Develop the technical content for addressing the priority problems identified
- Develop a time frame for incorporating the planned activities into the farming calendar
- Draw up a plan of work (annual, seasonal and monthly) for the implementation process
- Clarify the specific responsibilities of the farmers, community and opinion leaders and extension personnel during the implementation process.

Step 5: Design and implementation

Develop a wide range of technical solutions so that various groups and individuals in the community have the opportunity to select those that suit their conditions. Good land- management techniques should have the following characteristics:

- Be simple, so that land users can adopt them with minimum or little external support.
- Be low cost in terms of labour and cash requirements for construction and maintenance
- Should lead to significant short-term increases in yields or other benefits
- Should be site specific and tailored to the specific situation of the farmer
- The plan should be flexible so that adjustments can be made to fit changing situations during the implementation process.

  Remember that what works in one place may not work in another place.

Step 6: Monitoring and evaluation

- Organize regular small planning and review meetings to revise plans and propose improvements based on the experience gained, opportunities and new problems encountered.
- Make regular follow-up visits to supervise activities and gather routine information about the achievements and problems that have been experienced.
- Document all the important observations (achievements, problems and proposed changes).

9.6 Summary of recommendations for good land-management extension

- Respect existing traditional values and customs.
- Advice on land-management techniques should build on what people already know, starting from the known to the unknown.
- Land-management problems should be tackled step by step, starting with those activities that farmers can adopt easily. Complicated problems should be handled later when farmers have gained confidence and experience.
- Recommend those techniques that do not compete for available labour during peak maintenance periods in the farm production calendar.
- Provide a basket of techniques so that farmers can choose those that suit their abilities and capacity.
- Start work in a small area with a few farmers and a few groups so that supervision can be effective and mistakes can be easily corrected.
- Deliver land-management messages together with other relevant extension packages.
- The recommended approach should aim at improving soil fertility as well as soil-moisture content so that the benefits can be measured in terms of increased production rather than simply arresting land degradation.
- Ensure constant visits and supervision so that the initial interest shown by the farmers does not dissipate. This also helps to build confidence and a better working relationship between the extension agents and farmers.

References/Bibliography

Aboli A, Scully J. 1993. *Composting for the small farmer: how to make fertilizer from organic waste*. Nairobi: Foundation for Sustainable Development in Africa, United Nations Environment Programme (UNEP).

Assmo P, Eriksson A. 1994. *Soil conservation in Arusha Region, Tanzania: manual for extension workers with emphasis on small-scale farmers*. Nairobi: RSCU/Sida.

Critchley W. 1991. *Looking after our land: new approaches to soil and water conservation in dryland Africa*. Oxford: Oxfam.

Donisthorpe J, Wanjau NJ. 1993. *Farming for health: why organic farming is good for the land, the crops and the people who depend on the land*. Nairobi: Kenya Institute of Organic Farming (KIOF).

Government of Uganda. 1991. *National Environment Action Plan (NEAP)*. Entebbe: Government Press.

Katende A, Birnie A, Tengnäs B. 1995. *Useful trees and shrubs for Uganda: identification, propagation and management for agricultural and pastoral communities*. Nairobi: RELMA/Sida.

Kinsey E. 1993. *Integrated smallholder dairy farming manual*. Little Rock, Arkansas: Heifer Project International.

Mbuya LP, Msanga HP, Rufo CK, Birnie A, Tengnäs B. 1994. *Useful trees and shrubs for Tanzania: identification, propagation and management for agricultural and pastoral communities*. Nairobi: RELMA/Sida.

Ministry of Agriculture, Animal Industry and Fisheries (MAAIF). 1992. *Livestock technical handbook*. Entebbe, Uganda: Department of Veterinary Services and Animal Industry, MAAIF.

Ministry of Agriculture, Animal Industry and Fisheries (MAAIF). 1993. *Dairy husbandry guide for zero-grazing farmers*. Entebbe, Uganda: MAAIF.

Ministry of Agriculture, Animal Industry and Fisheries (MAAIF). 1995. Proposed National Soil and Water Conservation Programme, Project Document, Entebbe, Uganda: MAAIF.

Mudge KW, et al. 1992. Plant propagation: a teaching resource packet with emphasis on agroforestry and fruit trees in East Africa. New York: Cornell University Press.

Regional Land Management Unit (RELMA). 1997. *Roof water harvesting.* RELMA Working Paper. Nairobi: RELMA/Sida.

Rocheleau D, Weber F, Field-Juma A. 1988. *Agroforestry in dryland Africa.* Nairobi: ICRAF.

Sabiiti EN, Mwebaze S. 1989. Pasture/fodder development for dairy farming in Uganda. FAO consultancy report. Rome: FAO.

Sim D, Hilmi H. 1987. *Forestry extension methods*. Forestry Paper No. 80. Rome: FAO.

Tessema S, Emojong EE, Maluti M, de Leeuw PN. 1987. A new strategy of livestock research adapted to semi-arid small-scale mixed farming systems: the Katumani experience. In: Proceedings of the Third PANESA Workshop, Arusha.

Thomas DB (ed.). 1997. *Soil and water conservation manual for Kenya.* Nairobi: Soil and Water Conservation Branch, Ministry of Agriculture, Livestock Development and Marketing.

Wenner CG. 1981. *Soil conservation in Kenya, especially in small scale farming in high potential areas using labour intensive methods*. Nairobi: Project Management and Evaluation Division, Farm Management Branch, Ministry of Agriculture.

Appendices

Appendix I: *Uganda land capability classification*

Class	Characteristics	Recommended use	Limitations
CLASS I	Good fertile, deep and well-drained soils. Flat or nearly flat with low erosion hazard	Good arable land suitable for a wide range of crops, woodland and wildlife	Few
CLASS II	Relatively fertile; not deep; poorly drained, poor structure. Difficult workability. Moderately saline (*lunnyu*). Gentle slopes; moderate susceptibility to erosion	Good arable land. May also be used as Class I land	Some limitations. May require moderate conservation practices
CLASS III	Low fertility; shallow depth to bedrock; very slow permeability of subsoil; easily waterlogged	Arable land. May also be used as Class I land	Some limitations. May require special conservation measures
CLASS IV	Poor, shallow soils, susceptible to frequent waterlogging. Severe salinity, adverse climate. Steep slopes with severe susceptibility to erosion	Poor arable land, but may be used as in Class I, above	Severe limitations. May require very careful management
CLASS V	Low-lying land, subject to frequent flooding. In areas with a growing season that prevents normal crop production. Level or nearly level stony or rocky soils. Usually ponded areas for grasses or trees. Little or no erosion	Special arable use	Limitations too severe to allow practical solutions. Require intensive soil-conservation and improve-ment measures
CLASS VI	Shallow, stony soils with excessive wetness or overflow. Saline. Steep slopes with severe erosion hazard and severe climate	Not suited to annual cropping.Can be used for grazing, plantation crops or forestry	Severe limitations to cropping
CLASS VII	Shallow; stony; wet with salts. Very steep slopes. Unfavourable climate	Non-arable land. Use for rough grazing, forestry or wildlife protection	Very severe limitations to cultivation
CLASS VIII	Badlands; rocky or sandy beaches; river wash and other nearly barren lands	Land of no value for farming. Useful only for recreation, aesthetic value or wildlife	Very severe limitations to cultivation

Appendix II. *Summary of recommendations/requirements for production of various crops*

Crop	Variety	Seed rate	Spacing	Fertilizer application	Pest control	Comments
Maize	Longe-1, KWCA hybrids	25–28 kg/ha Longe: 25 kg is sufficient	75 x 50 cm	125 kg SSP/ha and 125–250 kg SA or CAN per ha	Use chemicals against stalkborer or close season	Intercrop with beans
Rice, upland	IRAT 112, NP2, NP3, UK1, UK2	50–80 kg/ha	30 x 5 cm	125 kg/ha SSP and 125 kg/ha of SA or CAN between establishment and flower initiation	Bird scaring from a week after flowering	Proper weed control. Harvest only dry heads, thresh in bags
Sorghum	Serena, Seredo are the only ones available to farmers through the Uganda Seed Project. For other varieties see your extension agent	10 kg/ha	90 x 30 cm for tall varieties 60 cm x 20 cm for shorter varieties	125 kg/ha SA and 125 kg/ha of SSP	Chemicals against shootfly, stem borers and midges. Also early planting and use of resistant varieties	Dress seed with Thiram or Furadan. May follow cotton in rotation. Has export potential in the region
Finger millet	Pepe 1, ENGENG Gulu E, Serere 1	5–10 kg/ha	Drilled or broadcast in rows 30 cm apart	Generally 125 kg/ha SSP at planting and 125 kg SA at 4 weeks	Physical, mechanical and chemical means to control Quelea and weaver birds	Should follow cotton, sweet potatoes, groundnuts or cowpeas in rotation. Clean weeding essential. Dress seed with Thiram
Beans	Umubano 2333 K20, K131, K123, MCM1015 OBA-1, MCM2001	45–90 kg/ha	50 x 10 cm to 60 x 10 cm	125 kg/ha SA and 125 kg/ha SSP both broadcast and dug in. Lime: below pH 5.8 apply 2.5 t/ha; below pH 5.2 apply	Use resistant varieties, early planting, optimum plant density, crop rotation, chemical control.	Intercrop with cassava or maize
Soya beans	NAM-1, NAM-2	30 kg/ha	60 cm x 5 cm, 2 plants per hole	150 kg/ha SSP in seedbed before planting, and 150 kg/ha CAN one month after planting	Soya is very resistant to pests and diseases	Soya beans are more tolerant of acid soils than beans. Seed should be inoculated

Appendix II. contd

Crop	Variety	Seed rate	Spacing	Fertilizer application	Pest control	Comments
Sunflower	New Sunfola for high oil content	4 kg/ha	75 cm x 50 cm	45 kg N or K avoiding direct contact with the germinating seedlings	Use chemicals, scaring of birds and baiting of rodents with rodenticides	Important for oil and seed cake. Same locality for growing and marketing and seed-quality control
Cotton	SATU (for N., E. Uganda), BPA (for S.W. Uganda)	20–25 kg/ha	60 cm between rows and 30 cm between plants for SATU, and 90 cm x 30 cm for BPA	125–250 kg/ha SSP or sulphate of ammonia	Resistant varieties, closed cotton season, uproot and burn old cotton stalks	Plant on new land if possible
Irish potatoes	Victoria, Kisoro and Kabale varieties release Uganda rutuku, Sangema, Maalirada	2,000 kg	70 cm x 30 cm (48,000 plants per hectare)	100:80: NPK 5 t/ha of FYM	Spray 2.5 kg/ha Dithane M45; also use resistant varieties, crop rotation and rouging	Mature, healthy seed, about size of chicken eggs, with multiple sprouts vital. Leave 4 of the strongest sprouts at planting. Protect seed from injury and rotting. Get fresh seed from good sources. Dig furrows 10 cm deep and 70 cm apart. Arrange the sprouts 30 cm apart and cover with soil.
Sweet potatoes	New Kawogo, Nylon, Kyebandula, Tanzania, Bizambi, Ecuru, Kisakyabiila, Maliya, Tororo-3, Bwanjule sowola Tanzania Wagabolige	1–2 cuttings at intervals of 30–60 cm	Bury 25–35 cm of the apical vine into the heaps (mounds) or ridges	Plant in deep fertile loam soils, 125–250/ha kg KCL, 125 kg/ha SA/CAN and 125 kg of SSP (SSP at planting and SA/KCL after rooting)	Chemical control and use of resistant cultivars, and rouging	Use varieties that are well adapted to each location. Plant in mounds or ridges

Appendix II. contd

Crop	Variety	Seed rate	Spacing	Fertilizer application	Pest control	Comments
Cassava	Nase 1, Nase 2k, Migyera, Bao, Bukalasa Bb, Bukalasa 11, Ebwanateraka. The last four are susceptible to African cassava mosaic	A total population of 10,000 plants per ha	1 m x 1 m	125–250 kg/ha SA, KCL and SSP applied twice per year. All broadcast	Control against cassava mosaic mealy bug and green mite. Use chemicals for cassava scale, but most important, use resistant varieties, crop rotation and rouging	Intercrop with beans or maize
Groundnuts	Igola-1 Roxo 531, Red Beauty (B1), (all resistant to rosette)	Bunch type 110 kg/ha, semi-erect type 90 kg/ha	Bunch type 45 cm x 10 cm, semi-erect type 45 cm x 15 cm	Plant in fresh fields after fallowing; 125 kg SSP applied at planting	Clean weeding, pest and disease control using PIM, a judicious combination of cultural, management and chemical methods	Careful seed handling. Leave seed in shell until shortly before planting. Nematode-prone crops should not come immediately before groundnuts.
Simsim	Sierra. EM-14 is due for release soon	6–8 kg/ha when broadcast	30 cm between rows and 10 cm between plants	Poor soils: 125 kg/ha SSP in the seedbed and 125 kg of N/ha at planting, or half that amount as side dressing after thinning to 50%	Efficient weeding essential. Chemical control for webworm caterpillars, gall midges and leaf spot	For seedcake and oil production. May follow millet in rotation

Appendix III: Botanical and local names of common grasses and legumes in Uganda

Type of pasture/ legume	Botanical name	Common name	Local names (language)
Pasture grasses	*Panicum maximum*	Guinea grass	*Edinyo* (Ateso) *Mukonzikonzi, Ccuccu* (Luganda) *Mukonde, Musekende* (Lugisu) *Odunyo* (Luo, Lango) *Orukonzi* (Runyoro) *Atok* (Luo,Acholi)
	Chloris gayana	Rhodes grass	*Ekode, Akono* (Ateso) *Kasibante* (Luganda) *Ombagkidyanga* (Luo) *Businyande* (Lugisu) *Kuku omunene* (Lusoga) *Runyankokore* (Runyankole)
	Hyparrhenia rufa	Daragua grass Thatching grass	*Apudu* (Acholi) *Elagara* (Ateso) *Likate* (Lugisu) *Nkabala* (Lusoga) *Orukabara* (Runyoro) *Rao* (Luo)
	Brachiaria riziziensis	Signal grass	*Ejubwa* (Runyoro) *Biryama* (Lusoga) *Kifuuta* (Luganda) *Lukoko* (Luo)
	Setaria anceps	Nandi setaria	*Kakira, Kambwa* (Luganda) *Alende* (Luo) *Orutaratumbwa* (Rutooro)
	Cynodon dactylon	Star grass	*Amachomensi* (Lugisu) *Oruchwamba* (Runyankole)
			Kalanda-lugo (Luganda)
Pasture legumes	*Neonotonia wightii*	Glycine	*Kavagombe* (Luganda)
	Desmodium intortum	Silver leaf desmodium	*Ebibowabowa* (Luganda)
	Macroptilium atropurpureum	Green leaf desmodium	*Ebikamba* (Runyankole)
	Stylosanthes guyanensis	Siratro	
	Centrosema pubescens	Sylo, Centro	
Fodder grasses	*Pennisetum purpureum*	Elephant grass	*Agada* (Luo) *Ebisagazi* (Luganda) *Ebibingo* (Runyakole, Rukiga, Rutooro) *Egada* (Ateso) *Ozu* (Lugbara)
	Tripsacum laxum	Guatemala grass	Referred to as 'gwatamala' wherever it grows
	Setaria sphacelata	Giant setaria	Tanzania grass
Fodder legumes	*Leucaena leucocephala*	Leucaena	No local names
	Cajanus cajan	Pigeon pea	*Nkombo* (Luganda)
	Dolichos lablab	Lablab	
	Sesbania sesban	Sesban	Muzimba ndegeya (Luganda)
	Calliandra calothyrsus	Calliandra	
	Gliricidia sepium	Gliricidia	

The Swedish International Development Cooperation Agency (Sida) has supported rural development programmes in countries in Eastern Africa since the 1960s. It recognises that conservation of soil, water and vegetation must form the basis for sustainable utilisation 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 organisations.

RELMA organises 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 publicise the experiences gained from its activities in the region, RELMA publishes and distributes various reports, training materials and a series of technical handbooks.

About this book:
Of the three East African countries, Uganda has the best natural-resource endowment in the form of good soils, abundant water and a climate that favours the production of a wide range of commodities. This potential, however, has not yet been fully realized. Of particular concern is the generally low level of agricultural productivity resulting from soil erosion, declining soil fertility, poor tillage practices, lack of supplemental irrigation, poor marketing outlets, and a lack of credit facilities.

This handbook has been produced to provide extension workers in Uganda with information on some of these subjects. The main areas covered are soil and water conservation and soil fertility, agroforestry, livestock, and extension. Given such a wide range of topics, the treatment of each subject is necessarily limited to general principles. Therefore it is clear that there is a need for more detailed guidelines on each of the main subject areas, and the authors hope that others will take up the challenge to write such materials for Uganda.

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