SOIL CONSERVATION IN ERITREA

Some case studies

Amanuel Negassi
Bo Tengnäs
Estifanos Bein
Kifle Gebru

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Regional Land Management Unit (RELMA)
2000
Foreword

Mismanagement of land resources emanating from successive colonial administrations in Eritrea has brought about severe land degradation. Soil erosion induced by rain is rampant in the central highlands, where the topography is mountainous and undulating with poor vegetation cover. There are insufficient data on the exact extent of the soil erosion in the country; however, it is estimated that 15–35 tonnes per ha of soil are eroded annually. Because of this, soil fertility is dwindling and agricultural productivity is similarly reduced.

In order to reverse this alarming situation, in the last seven years the Government of the State of Eritrea has made a concerted effort to mobilize the whole community to participate in soil and water conservation and afforestation activities. Under this programme, massive soil and water conservation terraces, both on farms and on degraded hillsides, have been constructed. On hillside terraces, a variety of indigenous and exotic trees and shrubs have been planted, while on farm lands efforts are focused on trying to stabilize the physical structures by planting multipurpose grasses. Local-level initiatives have also complemented these efforts, especially in the area of soil and water conservation on individual farms and the development of woodlots in homesteads and near villages.

Considering the magnitude of the problem of land degradation, however, much effort is still required in order to rehabilitate the degraded landscape.

Experts from the Ministry of Agriculture and the Ministry of Land, Water and Environment, with the assistance of the Regional Land Management Unit of Sida in Nairobi, Kenya, have prepared this report of some case studies conducted in different settings in the country. I would like to gratefully acknowledge the team’s efforts in conducting the studies and also extend my gratitude to RELMA for the invaluable support they gave in the preparation of this report. It is also my sincere hope that the users of the published report will help in the preparation of the planned soil and water conservation guidelines.

Mebrahtu Iyassu
Director General, Land Resources and Crop Production Department
Ministry of Agriculture
Asmara
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Map 1. The main physical features of Eritrea
1. INTRODUCTION

The Ministry of Agriculture of Eritrea and the Regional Land Management Unit (RELMA) agreed to produce a manual on soil and water conservation in Eritrea with financial and technical support from Sida. To ensure that the manual would be relevant to Eritrean conditions, it was agreed that the first step should be a brief review of actual field experience in Eritrea. The findings from this review are presented here in the form of a number of case studies from areas representing different agro-ecological conditions in the country. The findings were discussed at a workshop held in Asmara on 14 October 1998.

At the end of each case report there is a box headed ‘skills required’. This is a list of the skills that an extension worker in each of the areas would need in order to effectively deal with the issues, constraints and potentials noted as being relevant to that area. A summary of all these skills is presented in Appendix I.

1.1 Land tenure in Eritrea

Land tenure in Eritrea has been much influenced by a system known as ‘dessa’. The main characteristic of the dessa system is that all land within the designated area of a village is conceived of as being the common property of the community. Thus, every permanent member of the village is entitled to a share of village land through periodical redistribution every 5–7 years. Each villager’s land share is equal in size and fertility; that means every person receives as much of the fertile as of the poor land. This process of distribution of land is carried out by the drawing of lots, referred to as ‘echa’. This system provides equitable access to land for all members of the village. From the land-improvement point of view, however, the system has the following disadvantages:

- A rotation period of 5–7 years is too short for people to have the incentive to make long-term investments in improving the land, such as tree planting, digging water wells, making water canals and soil-conservation structures, etc.
- Crop land is open to communal grazing in the post-harvest season, which results in the removal of crop residues that could provide ground cover against wind erosion and additional organic matter for the soil
- Such land cannot be used as security to obtain credit.

When implemented, recent legislation is likely to bring changes to this tenure system.

1.2 Causes of soil degradation

Indiscriminate removal of the land cover over hundreds of years has resulted in serious soil erosion, decline of soil fertility, general land degradation and reduction of agricultural productivity in the highlands of Eritrea.
Map 2. The main agro-climatic zones of Eritrea
Soil erosion implies the physical removal of topsoil by various agents, including raindrops, water flowing over and through the soil, wind and gravitational forces. It is a two-phase process consisting of the detachment of individual particles from the soil mass followed by transport by erosive agents. This process leads to a general decline in soil productivity and, if unchecked, soil erosion can lead to catastrophic effects for human existence (Morgan 1991).

From time to time it has, however, also been argued that much of the agricultural development in the world has been linked to erosion in highland areas and development of agriculture in the lowlands. An example sometimes cited is the Mediterranean area of Europe. There, the mountainous areas were once more productive than nowadays. At present, the lowlands, where much of the silt from the highlands has been deposited, are the main agricultural areas.

1.3 Physical and biological methods of soil conservation

Physical soil-conservation measures are generally engineering works. They involve construction of physical earthworks such as terraces, contour bunds, checkdams, etc. These structures intercept and slow down runoff water, which then prevents both sheet and rill erosion and conserves water. The intercepted water soaks into the soil or, if excessive, is channelled into drainage structures off the farm. In Makel, Debub and part of Anseba Zones soil bunds, stone bunds and bench terraces are commonly constructed. In upper catchment areas, hillside terraces and half-moon-shaped micro-basins are also constructed.

Trees and shrubs stabilize conservation structures and contribute to productive use of the land they occupy. Grasses can also be effective in reducing soil erosion.
Map 3. The main towns and villages of Entrea
Methods using both trees and shrubs and grasses have recently received increasing attention in many African countries as cost-effective methods of combating land degradation.

However, in Eritrea few biological conservation measures have been implemented in the course of soil and water conservation activities in crop lands compared to those interventions based on physical conservation structures.

1.4 Conservation activities in Eritrea

Afforestation before independence

Between 1922 and 1932 some 1.2 million seedlings were planted in Eritrea. Only limited information is available on the extent of afforestation activities carried out in the country from that time up to the early 1970s. The colonial administration in Ethiopia planted trees on 1,586 hectares of land in Makel and Debub Zones from 1971 to 1978. Between 1979 and 1991, it is estimated that 27,000 hectares were terraced and planted with *Eucalyptus cladocalyx*, *Eucalyptus camaldulensis* and *Eucalyptus globulus*. These activities were carried out through the food-for-work programmes in which assistance was obtained from the EEC and WFP, but their success was minimal because of neglect and mismanagement. In addition, the Eritrean People’s Liberation Front (EPLF) mobilized farmers during the war through self-help programmes and about 900 hectares of land in the liberated areas were planted with trees.

Activities after independence

After independence, a series of painstaking soil conservation activities has been carried out on degraded catchments, including crop lands, by mobilizing local communities. Hillside terraces have been constructed on uncultivated land, and trees and shrubs have been planted to conserve soil and water and to produce fuelwood and construction poles.

On cultivated land, bench terraces, soil bunds and stone bunds have been constructed. Checkdams have been constructed along waterways to reduce siltation and runoff, and in the lower part of watersheds gullies have been treated.

1.5 About this study

This study was carried out by a team comprising an agro-ecologist, a soil conservationist and an agroforester. Initially, different typical ‘settings’ were identified as representative sites for different land uses in the country. These representative settings and expected examples of issues to be considered were:
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<table>
<thead>
<tr>
<th>Settings</th>
<th>Interventions/issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hillsides with no agriculture</td>
<td>Successful enclosures, hillside terracing, other structures (micro-basins, checkdams)</td>
</tr>
<tr>
<td>Crop land used for intensive rainfed agriculture, continuous cultivation ('ghedena')</td>
<td>Vegetative methods as well as various physical structures. Soil-fertility management</td>
</tr>
<tr>
<td>Crop land used for rainfed agriculture. Continuous cultivation or cultivation with fallow periods</td>
<td>Vegetative methods as well as various physical structures. Soil-fertility management</td>
</tr>
<tr>
<td>Areas within villages and permanent settlements</td>
<td>Tree planting, shallow wells, roof-water harvesting, livestock. Manure and organic-waste management</td>
</tr>
<tr>
<td>Areas around ponds and small earth dams</td>
<td>Catchment-area protection, use of water for horticulture and livestock</td>
</tr>
<tr>
<td>River banks</td>
<td>Different types of vegetation, potential and limitations for production</td>
</tr>
<tr>
<td>Roadsides</td>
<td>Planning for protection near culvert outlets, protection of roadsides, roadside plantation</td>
</tr>
<tr>
<td>Small-scale irrigation schemes, including spate-irrigation areas</td>
<td>Soil and water management</td>
</tr>
<tr>
<td>Large-scale irrigation schemes, including spate-irrigation areas</td>
<td>Soil and water management</td>
</tr>
<tr>
<td>Pastoral areas</td>
<td>Water conservation, land-use conflicts, e.g. irrigation versus use by pastoralists. Wind erosion. Land degradation near watering points</td>
</tr>
</tbody>
</table>

Information was gathered by interviewing farmers in the field, and in order to verify the information obtained from the farmers in this way, observations were also made through field visits to representative sites. Extension agents and local administrators were also interviewed.

1.6 Overall impressions as a result of the study

Few real successes have been recorded, especially on sloping crop land, in spite of massive investment in farmers' labour, tree seedlings and public funds.

An obvious lesson learnt is, of course, the necessity to work hand in hand with the local people and to ensure that all attempts to address issues of land
degradation take local knowledge into account. Following on from this rather general and sweeping statement, it is important to note that farmers are, at least to some extent, managers of soil erosion, not only spectators. The case studies in this report demonstrate how soil lost from sloping land is used by farmers wherever it is deposited. At the farm level, soil and nutrients ‘lost’ from the village or homestead are used in the intensively managed ghedena fields. This observation may call for a reconsideration of the concept of loss of soil and nutrients. At least as far as ghedena is concerned, and the important production from that type of farm land, it is certainly not a loss but a fundamental asset!

At the landscape level, soil and nutrients lost in the highlands are utilized along the river banks where sediments accumulate by siltation. The use of such riverine areas results in land-use conflicts, for example between commercial investors in horticultural production, pastoralists and people interested in conservation of the riverine vegetation.

At the national or macro level, soil lost in the Eritrean highlands and not deposited in the highland valleys is brought down the escarpments during peak flows to be utilized in the spate-irrigation areas in the lowlands.

The techniques involved in managing such deposited soil are well described in several case reports.

1.7 Conclusions from the workshop

As mentioned earlier, the findings of the survey were discussed during a workshop. Most participants were agricultural officers from within the Ministry of Agriculture (see Appendix II).

The discussions focused on deciding the most important areas to be highlighted in a manual for soil and water conservation for Eritrea. A long list of ‘skills required’ for an extension worker was developed, and workshop participants were asked to consider the priority subject areas in this list that in their opinion should be covered in such a manual (see Appendix I). Most of the points in the list were judged relevant.

In order to shorten the list, each workshop participant was asked to indicate the subject areas and agro-ecological settings that most deserve attention. The results were as follows.

Most important subject areas

- Physical and biological soil conservation
- Irrigation technology
- Dam construction and/or maintenance
- Soil fertility
- Extension communication
- Agroforestry.
Greater focus on land-use situations
● Catchment areas for dams
● Rainfed cultivated land
● Small-scale irrigation
● Hillsides
● Spate irrigation.

No/less focus on
● Pastoral areas
● Roadsides
● Ghedena.

A summary of the way the deliberations were conducted at the workshop is given in Appendix II.

2. TREATMENT OF DEGRADED HILLSIDES

2.1 The case of Tsehaflam

Introduction
Tsehaflam is in Makel Zone, Serejeka Subzone, 20 km north of Asmara along the main Asmara–Keren road. Some 970 people live in Tsehaflam and their main activity is agriculture.

The area has a temperate climate as it is in the Central Highlands at an altitude of 2,250 m. The annual rainfall recorded at the nearest meteorological stations of Afdeyu and Asmara varies between 400 and 600 mm. Lithosols and reddish brown Cambisols are the most common soils in the area. The natural vegetation cover and the soils are severely degraded as a result of centuries of intensive land use, and only a few plant species are still common. Some of these are Rumex nervosa, Aloe abyssinica, Cynodon dactylon, Echinops giganteus (dander) and Polygonum salicifolium.

It is estimated that soil is lost at the rate of 15–35 tonnes/ha/year in areas where there are no soil-conservation measures. This is due to the nature of the rainfall, the fragility of the soils, poor vegetation cover and the slope, which ranges from 15% to 40%. The Tsehaflam catchment drains into the Tokor, a tributary of the Anseba seasonal river.

Afforestation and soil conservation
In order to rehabilitate the degraded catchment, the Tsehaflam community started planting trees and terracing the hillsides. Areas selected for tree planting are those which are not suitable for agriculture. In the upper part of the catchment,
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A small area was planted during the Ethiopian colonial period. However, after liberation, larger parts of the catchment have been treated and planted with a variety of exotic and indigenous trees and shrubs.

**Table 1:** Areas treated and afforested, 1994–1997

<table>
<thead>
<tr>
<th>Year</th>
<th>Area (ha)</th>
<th>No. of trees</th>
<th>Species planted</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>22</td>
<td>43,240</td>
<td><em>Acacia abyssinica</em></td>
<td>2,500</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Acacia saligna</em></td>
<td>23,240</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Eucalyptus cladocalyx</em></td>
<td>16,500</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Olea africana</em></td>
<td>1,000</td>
</tr>
<tr>
<td>1995</td>
<td>27</td>
<td>54,540</td>
<td><em>Acacia saligna</em></td>
<td>1,600</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Eucalyptus camaldulensis</em></td>
<td>22,150</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Eucalyptus globulus</em></td>
<td>25,590</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Olea africana</em></td>
<td>500</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Schinus molle</em></td>
<td>4,700</td>
</tr>
<tr>
<td>1996</td>
<td>11</td>
<td>22,000</td>
<td><em>Acacia saligna</em></td>
<td>3,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Eucalyptus cladocalyx</em></td>
<td>15,500</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Eucalyptus globulus</em></td>
<td>3,500</td>
</tr>
<tr>
<td>1997</td>
<td>4</td>
<td>7,915</td>
<td><em>Acacia mollissima</em></td>
<td>500</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Acacia saligna</em></td>
<td>1,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Eucalyptus cladocalyx</em></td>
<td>4,650</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Eucalyptus globulus</em></td>
<td>1,500</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Schinus molle</em></td>
<td>265</td>
</tr>
<tr>
<td>Total</td>
<td>64</td>
<td></td>
<td></td>
<td>127,695</td>
</tr>
</tbody>
</table>

**Figure 2:** Tokor afforestation site—planted in 1994.
In the treated area, narrow trenches, commonly called ‘gradoni’, are constructed across the hillside and on the contours. The purpose of the terracing is to reduce runoff, increase infiltration and conserve soil.

Before terrace construction starts, a contour line is marked using a line level. The width of the terrace is 1 m. In areas where stones are available, a riser is constructed with stones and soil filled up behind the riser. If stones are not available, the whole terrace is made of soil dug from the contour line. The vertical interval between the terraces is 1 m, but the horizontal interval varies depending on the steepness of the slope. This means that in the upper part of the catchment, where slopes are steep, the horizontal distance between the terraces is small, and in the lower part of the catchment, where the slopes are more gentle, the horizontal distance between the terraces is greater.

Channels are formed when soil is excavated for the terrace. Ridges are left in a channel to prevent water from travelling too far horizontally and to reduce damage if water should overflow the channel during heavy rain. However, since the ridges are lower than the sides of the channel, water can spill over to other sections of the channel if one section becomes full.

Pits for planting seedlings are dug every 2.0–2.5 m. Theoretically, the dimensions of each planting pit should be 0.5 x 0.5 x 0.5 m, but it can be less than this if the site is difficult to dig.

The survival is very good (about 80%) and the success of this plantation is a result of:
- Good preparation of terraces which harvest sufficient water for plant growth and survival even during the long dry season
- The use of healthy and mature seedlings

Figure 3: Tokor afforestation and soil-conservation site while conservation work was being carried out.
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- Careful handling, transporting and planting of the seedlings
- Planting at the right time (early rainy season)
- Seedling and site matching
- Care after planting, i.e. protection from livestock, weeding, cultivation, etc.

Checkdams have been built in the waterway of the catchment area. A checkdam is a stone wall built across a natural or artificial waterway, or in the bottom of a gully, to reduce the speed of runoff. None of the checkdams in this catchment area have spillways in the middle to allow runoff; neither are there aprons on the lower side of the checkdams.

Constraints
Although some progress has been made in this area, there are still some shortcomings:
- Some hillside terraces do not follow the contour
- *Eucalyptus globulus* and *E. camaldulensis* are planted on hillsides, while they prefer valley bottoms and deep soils
- Checkdams do not have spillways in the middle, or aprons
- Seedlings are planted in subsoil since the topsoil is excavated to make the terrace risers
- A vertical interval of only 1 m between two consecutive terraces results in much of the soil being disturbed by digging
- The cost of terrace construction is more than 10,000 Nakfa (approximately equivalent to $US 1,330 at the time of the workshop) per hectare, which is too high to be cost effective.

Recommendations
In order to rehabilitate the highly degraded sites in Tsehaflam village, the following recommendations are made:
- All hillside terraces should follow the contour so that water can be properly accumulated for the survival and growth of seedlings
- The species should be appropriate to the site, and thus planting *Eucalyptus globulus* and *E. camaldulensis* should be avoided. Instead, other indigenous species like *Juniperus procera* and *Olea africana* should be mixed with exotic species well suited to hillsides, e.g. *Eucalyptus cladocalyx* and *Acacia saligna*
- Checkdams should be properly designed, including spillways, aprons, etc.
- The topsoil must be collected on one side during excavation, and after the terrace has been constructed, returned to the pits where the seedlings are to be planted
- Terrace spacing should be variable in order to leave more undisturbed space between consecutive terraces and allow the natural vegetation to regenerate. These vertical intervals could be 2 m, 4 m, 6 m, etc., depending on the remnant natural vegetation in the vicinity
- Other cost-effective structures like crescent-shaped micro-basins must be incorporated with hillside terraces, especially on gentle slopes.
SKILLS REQUIRED

- Layout of contours.
- Terrace construction.
- The ability to make decisions on appropriate spacing between terraces using a vertical interval that is decided according to soils, vegetation and steepness of slope.
- Construction of checkdams.
- Understanding the importance of topsoil as opposed to subsoil and applying that knowledge practically.
- Knowing the ecological requirements of the most common tree species.

2.2 Catchment treatment: the case of Aditeclai-Adighebru

Introduction

Aditeclai and Adighebru are two adjacent villages in the western part of Makel Zone, Berik Subzone, and have a joint local administration. The population of each is more or less similar at 300 and 362 households, respectively. The area is part of the western escarpment of Aditeclai and Adighebru catchment at the periphery of the moist highlands with a mean annual rainfall of about 500 mm. The elevation is 1,900–2,000 m and the soils are very shallow—mainly Lithosols on steep slopes and Cambisols on the gentle undulating upper slopes. *Acacia etbaica* and *Euphorbia abyssinica* are the dominant species in the natural vegetation.

Figure 4: Catchment treatment, Aditeclai–Adighebru.
Soil and water conservation and afforestation

An earth dam was constructed in the valley between the two villages in 1985. The capacity of the dam is estimated at 53,000 m$^3$. The total catchment area is about 500 ha. Since the catchment area of the dam was not protected, and because of some technical faults during construction, it immediately collapsed at the middle of the crest. In view of the need for water both for livestock and small-scale irrigation in the area, the dam was reconstructed in 1996. In order to reduce runoff, erosion and sedimentation, various soil conservation measures were undertaken and a variety of trees and shrubs planted. On the lower side of the dam, the inhabitants of the two villages have started small-scale irrigated farming to produce vegetables on 8 hectares of land, an initiative that seems very promising.

Upstream, hillside terraces and half-moon-shaped micro-basins have been constructed and checkdams in the natural waterways. The hillside terraces are spaced at a vertical interval of 1 m. The micro-basins are eye-brow shaped and sited in a staggered way along the contour to provide small basins to collect water that can be utilized by the tree seedlings. The width of each basin is 3 m and the riser height depends on the steepness of the slope. The spacing between consecutive basins is also 3 m and, therefore, there are 800–900 basins in one hectare.

On the upper periphery of the catchment there is farm land which is continuously cultivated. In these areas, on-farm soil conservation structures, mainly *fanya juu* and *fanya chini*, have been made. There the slope is less than 20%. *Fanya juu* terraces are made by digging a trench and throwing the soil uphill to form an embankment.

Below the dam site, similar soil conservation structures are being made by the inhabitants of Aditeclai through a cash-for-work programme in order to rehabilitate the degraded watershed.

The catchment area above the dam is well conserved and planted with various *Eucalyptus* and *Acacia* species. In the upper part, the majority of the trees are eucalyptus, but there are more *Acacia saligna* in the lower part. The survival rate of the planted seedlings is variable. In the upper part of the catchment, including the valley bottoms, the survival is good, i.e. more than 70%. However, in the lower part of the catchment, where the soil is very shallow and stony, survival is less than 40%. Natural vegetation such as *Acacia etbaica*, *Dodonaea angustifolia*, *Becium grandiflorum*, *Aloe abyssinica*, *Euphorbia abyssinica*, *Meriandra bengalensis*, and grass species such as *Cynodon dactylon* and ‘lahu’ (*Hyparrhenia* sp.) are, however, regenerating well.

Management of the plantation

The plantation in this catchment is managed by the respective communities. Two guards, one from each village, are assigned to protect the plantation from encroachment. These two guards are each paid 300 Nakfa per month by the Ministry of Agriculture. If livestock are found grazing on the protected area, the owner must pay 5 Nakfa for each small ruminant (sheep and goats) while the fine for cattle, donkeys and the like is 10 Nakfa.
Currently, the villagers benefit from grasses growing in the catchment area. Since 1996, all inhabitants of the community who own livestock have been allowed to cut grass for 3–4 days during May every year. The actual dates when grass can be cut are announced by the village administration. The grass is cut during the dry season because by this time of the year the grazing has been used up and this protected area is the only source of feed other than hay collected during crop harvest. At this stage, the grass may not be as nutritious as when green, but it is a good practice from the soil-conservation point of view as the grass seeds are dispersed before harvest and thus they immediately germinate at the beginning of the next rains.

**Constraints**
The following constraints to management of the catchment in this study area were noted:
- Community commitment to protecting the plantation site from livestock is poor
- In some parts of the catchment, the terraces are not properly constructed and thus they do not prevent soil erosion or catch enough water for the seedlings to withstand the long dry season
- Maintenance of soil conservation structures is seldom carried out as the people tend to expect cash payment even for maintaining existing structures
- The species planted in the catchment area are mainly *Eucalyptus cladocalyx* and *Acacia saligna* which are not multipurpose species that would also be useful for fruit and fodder
- Inadequate design of spillways on the checkdams, as well of hillside terraces, results in frequent damage to these structures.

**Recommendations**
- On such sites it is important to have a combination of micro-basin and hillside terraces in order to minimize the cost of establishment and to encourage regeneration of the natural vegetation between the conservation structures.
- Closing some parts of the catchment is recommended to encourage regeneration of the natural vegetation and to minimize the cost of rehabilitation.
- The cut-and-carry system should be given more attention by the community. Therefore, a large area should be closed on both sides of the stream in the lower part of the catchment. This would enhance the rejuvenation of the remnant natural vegetation, maintain biodiversity, reduce land degradation and increase livestock production. Under this system, favoured grasses could also be sown to improve the quality and quantity of pastures.
- Proper maintenance of the conservation structures should be carried out voluntarily by the people themselves as this would benefit the entire community.
- Appropriate forage production should be initiated to increase fodder for livestock.
- To improve the survival of seedlings on site, the quality of the seedlings in the respective nurseries should be improved.
Spot weeding and cultivation around the planted seedlings could enhance growth and infiltration of rainwater

Non-wood forest products such as honey could be obtained if the community placed beehives in the plantation sites.

SKILLS REQUIRED

- Ability to secure the full participation of communities in management and protection.
- Layout of contours, construction of terraces and other structures, both on cultivated land and on hillsides.
- Cost-effective designs (few terraces, micro-basins on hillsides).
- Knowledge of a wider range of tree species, for example those suitable for fruit and fodder.
- Ability to determine areas that need to be closed.
- Ability to identify areas on hillsides where tree planting is not worthwhile, e.g. where the soil is too shallow.
- Ability to determine when the cut-and-carry system would be a realistic option.
- Knowledge about tree-seedling quality and post-planting care.
- Knowledge about non-wood forest products, e.g. bee-keeping.

2.3 Hillside closure: the case of Mt. Bizen

Introduction

Bizen is 25 km east of Asmara along the Asmara–Massawa road in Semenawi-Keih-Bahri Zone, Ghinda Subzone. The topography is mountainous and the highest point is 2,480 m. The soils are mainly Lithosols on the steep slopes and Cambisols on the upper plateau. Mean annual rainfall recorded at the nearest meteorological station is 550 mm, and the climate is temperate. The mean maximum temperature of the area is 24°C, while mean minimum temperature is 7°C. The vegetation types in the area are open woodland, closed woodland and bush land.

Mt. Bizen was designated a permanent woodland closure in 1992. Closure of forest or woodland means that an area is put under full or partial protection intended to halt, or at least limit, human and livestock pressure on the area.

There is an old monastery at the top of the mountain occupied by many monks whose livelihood depends mainly on agriculture and livestock rearing. They especially utilize the areas called Adi-Leito, Zengergera, Zala-Awald, Grat-Adri, Zuguh, Zala-Abi and Zala-Gubo. The surrounding settlements, areas which may have an impact on the development of the closure, are Mogot, Laiten, Adi-Rosso, Nefasit and Embatcala.
In this closure, *Juniperus procera*, *Olea africana* and *Dodonaea angustifolia* dominate the vegetation. *Juniperus procera* is mainly found in the upper part, while *Olea africana* occurs below the juniper belt. Pioneer species like *Dodonaea angustifolia* and *Carissa schimperi* dominate the lower part of the closure. *Opuntia ficus-indica* is invading the area, especially in the lower part of the southern and western sides of the closure. Natural regeneration of the indigenous species is negatively affected as the opuntia cactus is highly competitive in demand for water and nutrients (see Table 2).

**Significance of the closure**

Historically Mt. Bizen was known for its species diversity, but due to mismanagement and encroachment, the vegetation became highly degraded. Considering the ecological importance of the area, Mt. Bizen was closed in 1992. Since then, the surrounding communities have been prohibited from farming, grazing, cutting of wood and settlement in the area. The objectives of the closure are to:

- Allow the vegetation to recover through natural regeneration
- Protect the endangered trees and wildlife species
- Control runoff and loss of fertile soils
- Enhance infiltration of water
- Create an attractive and scenic landscape
- Conserve biological diversity.

**Closure management**

The Mt. Bizen closure is classified as a ‘permanent closure’ under which the Government has reached an agreement with the concerned local government.
**Table 2:** Status of some species in the closure

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Vernacular</th>
<th>Abundant</th>
<th>Common</th>
<th>Few</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acacia abyssinica</em></td>
<td>Chea</td>
<td></td>
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<tr>
<td><em>Acacia etbaica</em></td>
<td>Seraw</td>
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<tr>
<td><em>Acokanthera schimperi</em></td>
<td>Mebtæ</td>
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<tr>
<td><em>Bersama abyssinica</em></td>
<td>Bersema</td>
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<tr>
<td><em>Buddleja polystachya</em></td>
<td>Metere</td>
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<tr>
<td><em>Calpurnia aurea</em></td>
<td>Hitsawis</td>
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<tr>
<td><em>Canthium schimperiana</em></td>
<td>Tselimo</td>
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<tr>
<td><em>Carissa edulis</em></td>
<td>Agam</td>
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<tr>
<td><em>Celtis africana</em></td>
<td>Chebaele</td>
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<tr>
<td><em>Croton machrostachyus</em></td>
<td>Tambuk</td>
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<tr>
<td><em>Dodonaea angustifolia</em></td>
<td>Tahses</td>
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<tr>
<td><em>Dombeya torrida</em></td>
<td>Tambuk debri</td>
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<tr>
<td><em>Ehretia cymosa</em></td>
<td>Kurwah</td>
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<tr>
<td><em>Euclea schimperi</em></td>
<td>Kiliaw</td>
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<tr>
<td><em>Ficus glomosa</em></td>
<td>Chekomte</td>
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<tr>
<td><em>Ficus sycomorus</em></td>
<td>Sagla</td>
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<tr>
<td><em>Ficus vasta</em></td>
<td>Daro</td>
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<tr>
<td><em>Heteromorpha arborescens</em></td>
<td>Murkus-tebi</td>
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<tr>
<td><em>Juniperus procera</em></td>
<td>Tsehdi</td>
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<td><em>Maytenus arbutifolia</em></td>
<td>Atat</td>
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<tr>
<td><em>Maytenus senegalensis</em></td>
<td>Arghudi</td>
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<tr>
<td><em>Maytenus undata</em></td>
<td>At-at</td>
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<td><em>Meriandra bengalensis</em></td>
<td>Nihba</td>
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<td><em>Mimusops kummel</em></td>
<td>Kumel</td>
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<tr>
<td><em>Nuxia congesta</em></td>
<td>Kentebera</td>
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<tr>
<td><em>Olea africana</em></td>
<td>Awlie</td>
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<tr>
<td><em>Otostegia integriofolia</em></td>
<td>Chindog</td>
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<tr>
<td><em>Phoenix reclinata</em></td>
<td>Agusuana</td>
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<tr>
<td><em>Plectronia bagojense</em></td>
<td>Shimarghe</td>
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<tr>
<td><em>Psida panctulata</em></td>
<td>Thehai-ferhet</td>
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<tr>
<td><em>Pterolobium stellatum</em></td>
<td>Kontetefe</td>
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<tr>
<td><em>Rhamnus staddo</em></td>
<td>Tsedo</td>
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<tr>
<td><em>Rhus abyssinica</em></td>
<td>Amus</td>
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<tr>
<td><em>Rhus natalensis</em></td>
<td>Teteale</td>
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<tr>
<td><em>Ricinus communis</em></td>
<td>Gulie</td>
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<tr>
<td><em>Rumex nervosa</em></td>
<td>Hehot</td>
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<tr>
<td><em>Sida schimperiana</em></td>
<td>Tifreria</td>
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<tr>
<td><em>Solanum polyanthemum</em></td>
<td>Korenet</td>
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<td>*</td>
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<tr>
<td><em>Teclea nobilis</em></td>
<td>Suluhi</td>
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</tbody>
</table>
administrators and community leaders to limit human and livestock interference. The closure is administered by the Zonal Office of the Ministry of Agriculture. The key actors in this are the Ministry of Agriculture, the Ministry of Local Government and the local people, including the monks of the monastery.

The Mt. Bizen closure includes the adjacent closures of Gheab, Midri-Felesti and Kebabi-Adi-Roso and covers some 40,000 ha. A limited area surrounding the monastery is set aside for the monks for farming and as a grazing area for their livestock. The closure is protected by guards assigned by the Ministry of Agriculture on a cash-for-work basis.

In the initial stage of the establishment of the closure, much resistance was observed from the pastoralists who come from the coastal plains, especially during May–June, as well as from the surrounding agro-pastoralists. During the dry season, most of the pastoralists from the coastal plains move up towards Mt. Bizen closure in search of pasture. During this time of the year, more than 1,500 cattle, 500 camels and 3,000 goats graze or browse at the periphery of the closure, and sometimes encroach into the protected areas. It has also been reported that individuals from the surrounding areas are felling trees, especially *Olea africana*, during the night. Despite these illegal practices, many trees and shrubs are regenerating. The local people can see the improvement of the vegetation cover that takes place after the establishment of the closure. However, they still argue that they need more grazing land, especially during the dry season. Cut-and-carry is not practised in this area, although it is allowed by the Ministry of Agriculture.

Although bush fires are not frequent in the closure, in 1995, an area estimated at 2,000 ha was burnt. The cause of the fire was not determined but it was suspected that nomadic pastoralists set the fire deliberately to demonstrate their opposition to the establishment of the closure. *Juniperus procera* and *Dodonaea angustifolia* were severely damaged by the fire.

**Constraints**

Although currently the problems encountered in the management of Mt. Bizen are less serious than initially, there are still many problems that require solutions:
- The villagers are now denied the benefits of grazing, and collection of firewood and construction wood that they used to enjoy before the establishment of the closure. Therefore, they often encroach on the closure illegally, especially at night.
- During the dry season, nomadic pastoralists come from the eastern lowlands and encroach on the closure in search of pasture.
- The monks constantly release their livestock onto the closure as it surrounds the monastery. Also they often cultivate land outside the designated area.
- Some poachers fell trees, especially *Olea africana*, on the closure at night.
- Extension services to the nearby communities, including the pastoralists, are provided from far away and are very limited.
Aside from protection, no other woodland/forest management is carried out in the closure.

**Recommendations**

- The closure should be divided into different areas by firebreaks and should be kept free from any vegetation that encourages fire. The orientation of the firebreaks should be carefully determined. Roads passing through the closure can also serve as firebreaks if they are well maintained and free from grass and other vegetation.
- The negative effects of fire should be explained to the local communities through the mass media, public meetings and other extension services.
- Fire-protection equipment should be in place.
- Fire towers should be erected at the corners of the closure.
- There should be more guards assigned to protect Mt. Bizen closure and they should be well organized.
- The community surrounding the closure should be aware of the objectives of managing it and participating in its protection by understanding that they will get the benefits such as firewood and other non-wood forest products (hay, wild fruit, honey, medicine, etc.).
- Extension agents of the Ministry of Agriculture, as well as administrators, should integrate their conservation efforts.
- The cut-and-carry system should be encouraged to improve the supply of hay for livestock during the dry season and to reduce the risk of bush fires.
- The monks must collaborate in managing the closure. If the area is well protected, the monastery will be well respected.
- So far, no forest-management measures have been introduced other than protection. However, it is vital to encourage regeneration through enrichment planting with indigenous trees and shrubs in gaps, especially where land was previously used for cultivation.

**SKILLS REQUIRED**

- Community interaction.
- Methods for securing the people’s participation.
- Fire prevention.
- Extension methods.
- The ability to design and implement a forest-management system that secures benefits for the communities.
- The ability to determine when it is realistic to use the cut-and-carry system.
- Knowledge about tree-seedling quality and post-planting care.
- Knowledge about non-wood forest products, e.g. bee-keeping.
3. INTENSIVELY CULTIVATED LAND (‘GHEDENA’): THE CASE OF EMBA-DERHO

3.1 Introduction

Emba-derho is located in the Makel Zone, Serejeka Subzone, about 12 km north of Asmara, and it is one of the biggest villages in the highlands with about 1,200 inhabitants. It is accessible by a tarmac road.

Most of the Emba-derho area is undulating, gently sloping terrain. Both the gentle slopes and the plains in between are arable areas. There are also steeper hills which are mostly used for grazing. The altitude is about 2,200 m.

The dominant soils are Lithosols, Cambisols and Luvisols. These soils are generally very shallow, being even less than 20 cm deep in highly eroded uncultivated areas. In the lower plains, where there is a deposition of soil eroded from higher areas, the soil depth varies between 0.8 and 1.5 m. Soil management is very poor. Because of severe erosion and continuous cropping, the organic content, and thus the fertility, of the soil is low resulting in low yields.

The climate is mild to fairly cold with a rainy season from June to August and annual rainfall of about 500 mm. In recent times, the annual rainfall is said to have decreased significantly and the distribution and frequency are said to have become unpredictable and irregular.

The natural vegetation of Emba-derho used to include the following species:

- *Rumex nervosa*
- *Euphorbia* spp.
- *Echinops giganteus*
- *Aloe* spp.
- *Cynodon dactylon*
- *Hyparrhenia* spp.

However, due to intensive use of the land, the vegetation is now sparse. Very recently an attempt was made to rehabilitate the vegetation. Various eucalyptus and acacias were planted, and there is also a small area set aside as a closure.

3.2 Land tenure

The land-tenure system in Emba-derho and the surrounding areas is what locally is called ‘dessa’. In a dessa system, the land is owned communally by the whole village and is redistributed every 5–7 years. In the past, only married male members of families were eligible to be allocated land, but very recently a new system was introduced by a Government decree allowing both women and men over the age of 18 to obtain land. The land redistribution is performed by elected representatives, normally community elders. Every eligible person in the village gets an equal amount of land (1.0–1.5 ha), normally in three different locations.
3.3 Soil conservation

Soil erosion in Emba-derho is very severe, especially in the crop land, water erosion being the dominant type of erosion.

The only land rehabilitation measures taken by farmers are manuring and terrace maintenance. Although these are carried out every year, they are not done properly. As the number of animals is decreasing every year, manure becomes scarce and now most fields are planted without the use of any manure at all. When manure is available, it is applied to selected fields only. As crop yields decrease because of poor management and drought, farmers become less interested in their land and many fields are poorly managed. Now only a few farmers maintain their terraces properly, and only those farmers who own a good number of animals can apply manure.

There is a Government-sponsored cash-for-work programme in Emba-derho. Under this programme the farmers are encouraged to rehabilitate and maintain the terraces in their fields. On the whole the outcome is encouraging, but it has been noted that physical measures alone are not very effective. Allowing animals to graze freely on terraced fields, and thus destroy the terraces, or to graze the protective grass cover, has a negative effect.

3.4 The ‘ghedena’

Crop fields located very close to the village that receive water draining from the village during the rains are known locally as ‘ghedena’.

Animal droppings, household waste, including ash, and eroded soil from the village are carried to the ghedena fields and the flow controlled by well-maintained terraces. As a result, the ghedena are very productive and are highly valued and well cared for by farmers everywhere in the highlands of Eritrea.

3.5 The ghedena in Emba-derho

The total area of ghedena fields in Emba-derho is estimated at 120–140 hectares, but it is divided into several small plots. The fields consist of constructed bench terraces and successive deposition of silt. The vertical distance between successive terraces is usually 0.3–0.8 m, but may be up to 1.5 m in some places. Depending on the general slope, the horizontal interval between terraces varies from 6 to 15 m.

The terrace risers and edges are covered with grass, mainly Bermuda grass, and cutting is prohibited before the end of the cropping season. After the crops are harvested, the grass is grazed communally by all the animals in the village. This system allows the grass to spread during the rainy season, and this is effective in stabilizing the terraces. The terraces are further strengthened by adding soil clods during ploughing or by periodically raising them by digging soil adjacent to the terraces and adding it to the terrace edges. This may create waterlogging for
a few days, but prolonged waterlogging that would be harmful, especially when the crop is young, is prevented by making an outlet in the bunds.

3.6 Cultural practices

Land preparation

Ghedena fields are ploughed two or three times using oxen. The traditional plough that is used is usually made of wood with a metal spear-like head embedded in the tip. The metal tip breaks up the soil, while the flat wooden blades turn the soil over to each side. The first ploughing is done along the contour and the second across the contour.

Land preparation begins just after the first rains, so that the water-holding capacity of the soil can be improved. Large clods of soil are either broken into pieces or thrown on top of the bunds on the terrace edges.

Sowing

Ghedena fields are normally sown earlier than other fields when the soil is just sufficiently moist. Seed is broadcast by hand and ploughed under using the local plough and following the contour lines.

Weeding

The first weeding is usually done by hand since it is essential to weed when the plants are still very small and using a local plough at this stage could destroy the plants. The second and third weedings are performed either by hand or with a local plough. During the second and third weeding, weeds are not buried in the soil but carefully collected and fed to animals. This constitutes the only animal feed available during this period. Sometimes, the weeds are thrown on the top of the terraces to strengthen them and help to conserve moisture. This practice is beneficial.

Cropping

Unlike other fields, the ghedena fields in Emba-derho are normally planted only with maize. In the past, potato crops were alternated with maize, but because of blight, potatoes are no longer planted as extensively as before.

Maize is now valued highly by farmers for the following reasons:
● It can be planted very early and matures before other crops, and it can be consumed even before it is dry thus helping avoid family food shortages. Maize cobs can be sold and fetch a good price.
● After the harvest, weeds and maize stover can be used for animal feed, especially for oxen. Sometimes maize is intercropped with horse beans.

Intercropping, though proven to improve production, is rarely practised by these farmers. This is because it is difficult to prevent children damaging the crop when they go into the fields to collect green beans to eat.
Soil Conservation in Eritrea: Case Studies

**Harvesting**
Harvesting is done by hand. Mature dry crops are cut by hand using sickles, placed in heaps and allowed to dry thoroughly before threshing.

**Soil-fertility management**
Since the ghedena fields are so valuable to the community, there is a social obligation to ensure that they receive inputs of nutrients every year. A farmer who does not maintain the fertility of his ghedena is looked down upon. This fertility of the ghedena fields is sustained in three ways:

- **Manure**: Organic manure consisting of animal droppings and household waste is often used. Animal manure, if not used as fuel, is collected every day and stored in the back yard. A few days before the first ploughing, the manure is carried to the fields on donkeys and spread on the field. It is then ploughed under and thus mixed with the soil. The amount of manure applied varies from farmer to farmer, but is normally less than the recommended amount.

- **Inorganic fertilizer**: Inorganic fertilizers such as DAP and urea are virtually unknown. There are very few attempts to apply them to the fields, and if so at a very low rate. Farmers fear that during drought the fertilizer might ‘burn’ the plants and they would risk losing the entire crop. Consequently, they only apply 16–40 kg fertilizer per ha, which is too little to have any significant effect.

- **Sediment trapping**: As described above, the ghedena fields also benefit from organic residues washed down during rains from the nearby residential areas. This contributes greatly to production, provided the terraces are sufficiently well constructed to trap the sediments. The benefits of these trapped sediments containing much organic matter and fertile topsoil are well understood by the farmers and thus they make great efforts to take advantage of this.

**Case study: Tesfom Kifle’s farm**
Tesfom Kifle is a farmer in Emba-derho. He owns a 0.06 ha ghedena. Some years ago he used to grow potatoes, but now he only plants maize because of potato blight. He does not take good care of his ghedena field. The only maintenance work he does is during ploughing when he adds large soil clods to the terrace and thus increases its height. Unfortunately, his field is not yet quite level; part is gently sloping and therefore does not conserve moisture as it would if properly levelled. He says that production in this part of his field is significantly poorer, but he does not make any effort to level the whole field. Tesfom is satisfied with the yields he gets from his field, however.

Because the maize in the ghedena field is planted earlier than the crops in other fields, it also matures early when most farmers have little to eat. So Tesfom collects green cobs every day for his family until the other crops are ready for harvest. Last year he also sold about 700 kg of maize cobs on the market. In addition, he gets enough feed (weeds and maize stalks and leaves) for his animals (5 cattle and 1 donkey) during the time of most critical fodder shortage.
Constraints
The ghedena fields are usually well looked after. Deposition of silt and organic matter from the inhabited areas depends on its movement from those areas, where the soil loss may cause problems. But at the same time, this is a prerequisite for productivity of the ghedena.

Recommendations
It is essential to regard each village and its ghedena fields as one entity. Any activities aimed at curbing erosion in the inhabited areas may reduce the augmentation of soil fertility in the ghedena, but there will always be some runoff bringing with it animal droppings and soil that improve fertility.

SKILLS REQUIRED
Understanding the importance and management of ghedena.

4. CROP LAND FOR RAINFED AGRICULTURE

4.1 The case of Abarisom village

Introduction
Abarisom village is in Southern Zone, Adiquala Subzone, about 30 km south of Adiquala town. The topography is flat to undulating at an altitude of about 1,600 m. The village is accessible by the 27 km tarmac Adiquala-Indageorgis road and then a 3-km gravel road west from Indageorgis.

Abarisom is in the warm moist lowland zone where the climate is influenced by the adjacent moist highlands which have a main rainy season from June to the end of September with light showers during April and May. According to climatic data from the meteorological station at Adiquala, the average annual rainfall is 500–600 mm.

The dominant soils on the flat area are Luvisols and on the gentle slopes Cambisols, while on the floodplain, Fluvisols are also found. The soils are deep with a high infiltration capacity.

Some dominant species in the natural vegetation of the area are Acacia seyal, Acacia senegal, Ziziphus spina-christi and Balanites aegyptiaca, and there is a good cover of various lowland tree species. Acacia senegal occurs in both natural and planted stands, the latter by the Ministry of Agriculture. Both Acacia seyal and A. senegal are important trees economically as they produce valuable gum. Forest cutting and burning is common in the area. Trees are cut for fuelwood and for construction materials, and burning of trees and bushes is common to encourage regrowth of grasses and to kill harmful insects, rodents and reptiles.
Soil Conservation in Eritrea: Case Studies

The main source of water for the village is seasonal streams and the River Mereb. During the dry season, water is collected from shallow holes dug in the river beds. Water harvesting from roofs is an unknown method in this area.

Crop and farming practices
The major crops in the area are:
● Finger millet
● Sorghum
● Taff
● Groundnuts
● Maize.

Finger millet fields are ploughed twice in the first quarter of the year and then ploughed and planted simultaneously at the beginning of May. Thinning is done when the crop is knee high, first weeding in July and a second weeding at the end of August. Harvest time is from mid-December to mid-March.

Land for sorghum is ploughed and the crop sown at the same time during June. No thinning or weeding are practised, but manure and fertilizers are used. Harvesting is in November–December.

For taff, the first ploughing is done at the end of June, the second ploughing in mid-July and the third ploughing and planting from mid-July to the beginning of August. Weeding is done twice during August. No manuring is done, and harvesting is in November–December.

For maize, manure is applied in April before the first ploughing which is done from early May to June. The second ploughing and planting is done 3 days after the first ploughing. Thinning is done when plants are knee high, and weeding during August. Harvesting is in November–December.

For groundnuts, the first ploughing is done in June and the second ploughing and sowing in July. Sowing is either in rows or by broadcasting. Thinning is done 21 days after planting and weeding 21 days after thinning. No manure is applied.

Cotton and sesame can be grown in the area, but the people do not cultivate these crops on a large scale. Maize is grown as a homestead crop near the villages.

Maize fields are generally given priority with regard to application of manure, whereas other fields receive some manure through the practice of keeping livestock there during the night in the dry season.

Soil conservation
Hillside terraces and bunds are common on steep slopes in the area. Proper application of soil-conservation techniques on cultivated land is not common except that some ridging between plots is practised to retain runoff water. Therefore, soil erosion is severe not only on steep slopes but also on flat and gently sloping land.
Case study: Mohammed Nur’s farm

Mohammed Nur owns 1.5 ha of land. As he has no oxen himself, he arranges with another farmer who has a pair of oxen to cultivate his land. The two farmers then divide the harvest equally.

Part of the field is planted with taff and the other part is under finger millet. Due to exceptionally good rain during this season, the stands of both crops are good.

Mohammed indicates the following yields as normal from his fields:

<table>
<thead>
<tr>
<th>Type of crop</th>
<th>Good year (kg/ha)</th>
<th>Bad year (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finger millet</td>
<td>1,200</td>
<td>50–200</td>
</tr>
<tr>
<td>Sorghum</td>
<td>1,800</td>
<td>600</td>
</tr>
<tr>
<td>Taff</td>
<td>600</td>
<td>150</td>
</tr>
<tr>
<td>Groundnut</td>
<td>600</td>
<td>300</td>
</tr>
</tbody>
</table>

Mohammed rotates the crops as follows: sorghum–taff–finger millet–taff–sorghum. Maize is not rotated with other crops, but there is rotation of different maize varieties, e.g. Greek Chenfer and Biuh varieties.

He does not use manure because he does not have livestock, and neither does he use inorganic fertilizers.

Constraints

The major constraints in land use in the area are:
- Soil erosion resulting in poor fertility
- A shortage of draught animals
- Lack of good-quality seeds
- Shortage of extension agents resulting in ignorance about improved farming practices
- Sparseness of trees.

Recommendations

The following measures should be considered:
- Training for farmers in agronomic practices at village level
- Provision of draught animals on a credit basis
- Afforestation and soil conservation activities be given priority
- Farmers should be encouraged to use intercropping in order to increase yields
- Farmers should be supplied with good varieties of seeds that are adapted to the climatic conditions of the area
- The existing physical soil conservation activities should be complemented with biological soil conservation.
SKILLS REQUIRED

- General agricultural knowledge: seeds and agronomic practices.
- Knowledge on intercropping: suitable crop combinations, etc.
- Knowledge on afforestation.
- Knowledge on physical and biological soil conservation measures and how they can complement each other.

4.2 The case of Mekalasit village

Introduction

Mekalasit village is located in Anseba Zone, Keren Subzone, about 15 km north of Keren town. The site is accessible by the Keren–Afabet all-weather gravel road. The area is sparsely populated and the local economy is based on farming and rearing of livestock. The village is in a valley surrounded by mountains.

Mekalasit is in the dry highlands with a mean annual rainfall of approximately 300 mm. The rains usually start in June and last until the middle of September, but the rainfall is erratic and its effectiveness for crop production depends largely on its distribution over the season. The crop-growing period is between 60 and 90 days, and in most years rainfall is sufficient only for drought-resistant crops.

The natural vegetation in this area is relatively undenuded because the inhabitants fled the area for a long time as a result of the war. Some common species are:

- *Acacia abyssinica*
- *Acacia mellifera*
- *Acacia seyal*
- *Acacia tortilis*
- *Balanites aegyptiaca*
- *Ziziphus spina-christi*.

There are also various grasses such as *Cynodon dactylon*, *Aristida* spp. and *Hyparrhenia* spp.

Major soil types are Cambisols, Lithosols, Fluvisols and Regosols. Cambisols occur on the gentle slopes and undulating land where most of the cultivated land is situated. Lithosols and Regosols are found on steep slopes and mountainous areas where severe soil erosion occurs.

In the past, the land was owned individually with each person having absolute rights over his own piece of land. According to Land Proclamation No. 58 of 1994, all land in the country now belongs to the Government, but in Mekalasit the farmers continue to use their former land without rotating occupation, i.e. they are not following the dessa system.
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Soil conservation and soil fertility

The types of soil conservation structure found in this area are hillside terraces and stone and earth bunds which have been constructed by the Ministry of Agriculture through the food-for-work programme. The farmers do not construct bench terraces.

Direct application of manure to farm land is not common. However, there is indirect manuring where livestock graze on the fields after the harvest. Farmers with larger numbers of livestock manure their land by keeping animals in the fields overnight for several days during the dry season.

No leguminous crops that could improve the soil fertility are grown.

Major crops and farming practices

The important crops in the area are sorghum and pearl millet, and crop rotation is a simple alternation between the two. Most farming activities such as ploughing, cultivation and threshing are done by one man with a pair of oxen. Weeding and harvesting are done by men, women and children.

Seeding is done by broadcasting. The seeds are broadcast and ploughed under immediately for optimum germination and protection against birds and insects.

For sorghum, the land is ploughed and the seeds are sown at the same time in mid-June. Manure or fertilizers are not applied. No thinning is done, but a first weeding is done from July to mid-August and a second weeding in early September. Harvesting is done from the end of October to November. For pearl millet, the land is also ploughed during mid-June and the seed sown at the same time. No thinning is carried out, but weeding is done during August, and harvesting from the end of September to mid-October. Typical yields are as follows:

<table>
<thead>
<tr>
<th>Type of crop</th>
<th>Good year (kg/ha)</th>
<th>Bad year (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorghum</td>
<td>800</td>
<td>100</td>
</tr>
<tr>
<td>Pearl millet</td>
<td>600</td>
<td>150</td>
</tr>
</tbody>
</table>

Constraints

The major constraints are:

- Soil erosion resulting in poor fertility
- Shortage of draught animals
- Lack of good-quality seeds.

Recommendations

The following recommendations can be made:

- Implementation of afforestation activities should be encouraged
- Training farmers in modern farming practices should be considered
Application of biological soil conservation practices such as intercropping, planting of leguminous crops, mulching, strip cropping, etc.

Application of manure and inorganic fertilizers should be encouraged.

SKILLS REQUIRED

- Knowledge about afforestation.
- Training skills.
- General agricultural skills.
- Knowledge about biological soil conservation measures.
- Knowledge on use of manure and fertilizers and other methods of maintaining soil fertility.

5. VILLAGES AND PERMANENT SETTLEMENTS

5.1 The case of Afdeyu

Introduction

Afdeyu village is located in Makel Zone, Serejeka Subzone, about 22 km north of Asmara. It is accessible by a 20-km tarmac road from Asmara and a 2-km gravel road from Serejeka. The altitude is about 2,300 m. Afdeyu is on a plateau with gentle slopes, but including some hilly terrain. The total population of Afdeyu is about 1,650, or about 330 households, and their livelihood depends on farming.

Figure 6: Village woodlot, Afdeyu.
Afdeyu is within the moist highland zone, the climate being characterized by a rainy season from June to the end of September and light showers during April–May. The average annual rainfall recorded at Afdeyu meteorological station is 450–500 mm. The dominant soils of the area are Lithosols, Cambisols and Luvisols.

Water for both people and livestock is supplied from one borehole with one water pump and a small partially broken earth dam. This source is fairly far away from the village and the road is steep. The water is carried by women and young girls on their backs.

Some farmers have a system of collecting and storing manure and household ash in a pit. Others keep the manure on the ground and then apply the dried undecomposed manure and ash to the fields just before land preparation.

During the last century, the Afdeyu area was covered by juniperus and olea trees. But since it is near Asmara, the farmers used to cut and sell these trees to subsidize their cash earnings. During the war years, most farmers abandoned their land because of insecurity and instead depended on selling fuelwood, and at the same time the Ethiopian army, which was concentrated in the area, also destroyed trees to meet their firewood needs. Large amounts of wood were also cut for constructing traditional houses (*hidmo*). As a result, soil erosion by rain and wind is a serious problem on the steep slopes.

Currently, the soils are very shallow and have low fertility, poor moisture-retention capacity, little resistance to erosion and produce little crop cover. Wind erosion occurs on arable and fallow land, especially in the dry season when first ploughing starts before the onset of the rains. The torrential nature of the rainfall results in erosion.

The major crops grown in the area are:
- Barley
- Horse beans
- Wheat
- Flax
- Maize
- Peas
- Potatoes.

Crop yields vary from year to year depending on the reliability of the rains.

**Land tenure**

The dessa land tenure system has been practised for a long time in Afdeyu. Although in principle all land now belongs to the state, in practice the old communal tenure system is maintained but farm land will not be rotated until actual implementation of the new land law.

**Constraints**

The major constraints to land use at Afdeyu are:
- Lack of awareness in utilizing grass from the area closure by cut and carry
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- Lack of knowledge about the requirements for planting a wider range of tree species
- Lack of knowledge about improved farming practices
- Lack of knowledge about and finance for roof-water harvesting
- Lack of knowledge about use of decomposed manure on the part of some farmers.

**Case study: Yosief Kiflemariam and Samuel Yosief**

Yosief Kiflemariam and Samuel Yosief are father and son. Yosief is 73 years old and Samuel 31. They have 0.4 ha of farm land, 7 sheep and 2 donkeys.

Samuel has planted 19 eucalyptus trees since 1991, 11 of which are now big, in a fenced 3 x 14 m area near his house. The seedlings were bought from a farmer for 50 cents each and were planted mainly to supply wood for house construction. The seedlings were watered for six months until they were well established and thereafter rainwater was channelled to them from roof catchments through gutters and a wooden pipe.

In principle, cutting down privately owned mature trees is allowed by the Ministry of Agriculture at an individual farmer’s discretion. But the Afdeyu community normally require that the owner of the trees obtain permission to do so from the village administration.

**Recommendations**

The following recommendations are made:

- The farmers could utilize the grasses growing between the trees in the plantations for cut-and-carry to feed their livestock.
- The farmers of the village should be given training on how to prepare and preserve decomposed manure for application to agricultural crops and tree plantations.
- Better information should be provided to the farmers on which species of trees and shrubs are best suited for the different environments.
- The farmers need training in gully protection, preparation of diversion ditches and roof-water harvesting.
- Farmers need information on how to use mulch for tree seedlings.
- Ministry of Agriculture extension agents should support the community in providing fruit- and forage-tree seedlings adapted to the area. The fruit trees can be planted in the homestead, while the forage seedlings can be planted on areas similar to the tree plantation or on farm boundaries.
- Each household with a corrugated-iron or wooden roofed house should try to harvest water from the roof during the rainy season to save the time and energy normally spent fetching water from far away.
Case study: Sumon Tsegai

Sumon Tsegai has 21 trees, of which 4 are *Schinus molle*. He planted the seedlings in 1992 and raised them himself on a 10 x 10 m plot of land located near his house and a stream. He also has some cactus plants (*Opuntia ficus-indica*) and uses the fruit for family consumption and the leaves for animal feed. They were planted several years ago as a fence.

The farmer collects animal manure and crop residues and mixes them with water from a diversion ditch during the rainy season. The decomposed manure and crop residues are used as fertilizer for the cactus plants but not the trees as there is an insufficient amount for both. The application of manure on the cactus plants has led to improved yields and bigger and better-quality fruits.

Sumon Tsegai sets a good example for encouraging other farmers to plant fruit trees in their homesteads to supplement family food supply. The cactus benefit the farmer in three ways: the fruits are edible, the leaves are a good source of animal feed, and it is excellent for controlling soil erosion and flooding. As Sumon Tsegai has already become conscious of the need to plant fruit trees, he and his neighbours could be encouraged to plant more such trees of different species.

SKILLS REQUIRED

- Knowledge about management of manure and crop residues.
- Knowledge about fruit and fodder trees.
- Knowledge about roof-water harvesting.
- Knowledge about techniques for gully protection and diversion ditches.
- Knowledge about different multipurpose tree and shrub species for different environments.
- Knowledge about the cut-and-carry system, especially to determine when it is feasible and when not, e.g. with regard to distance.
- Knowledge about the use of mulch on tree seedlings.

5.2 Tree planting within villages: the case of Kitmewlie village

Introduction

Kitmewlie is a village located in Makel Zone, Gala-Nefhi Subzone, along the Asmara–Himbirti road, 12 km southwest of Asmara. The topography is more or less flat around the village and undulating towards the north and south. On the flat area, the soils are Luvisols, on the gentle undulating slope Cambisols, and on the valley sides Lithosols. Being in the moist highlands, Kitmewlie enjoys a temperate climate with a mean annual precipitation of 500–600 mm. The surrounding area is more or less bare and mostly arable land. Adjacent to the
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village there are scattered *Acacia etbaica, Euclea schimperi* and *Dodonaea angustifolia* shrubs.

There are 410 households in the village and the total population is 1,932. The average landholding is estimated at 0.4 ha, and because of a severe shortage of land many inhabitants of the village engage in other casual work in Asmara and elsewhere. The number of livestock in the village is estimated at 1,849, out of which 1,360 are goats and sheep.

**Homestead tree planting**

Kitmewlie is a village where homestead tree planting has become a part of the culture over the last 10 years and is practised by every member of the village. They also plant trees in school and church compounds. As the village is very close to Asmara, most of the natural woodland has been cut and sold for firewood. An increasing population in the village has also contributed to the increase in demand for wood, both for domestic firewood and house construction, and land for agriculture. The supply of wood for household consumption is now very limited and the villagers are only allowed to collect firewood from the protected communal woodland three times a year, i.e. at Christmas, Easter and Epiphany, and only one head load per household on each occasion. Therefore, this situation has obviously influenced the community to plant trees on their plots.

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**Case study: the farm of Sbhatu Ghebrekiristos and Woini Fsehaye**

Sbhatu Ghebrekiristos and Woini Fsehaye are husband and wife. They have 2 children and own 0.4 ha of farm land on which they grow sorghum, maize, barley, finger millet and taff.

There are 60 *Eucalyptus cladocalyx* trees in front of their hidmo (house) planted in 1992. The seedlings were obtained free of charge from Abardae forest nursery. During the rainy season, runoff from the roof catchment is diverted to the young trees. To protect the trees from livestock, the plot is fenced with a stone wall about 1.5 m high. According to Woini (whom we interviewed), the trees are intended for construction poles for renovating their hidmo. She also expects to obtain firewood from the trees if they grow well. As with other village households, they also cut and collect one load of *Acacia etbaica* for firewood three times a year and animal dung and crop residues from the field for fuel. They have one kerosene stove and use 4 litres of kerosene every three weeks.

The family has one ox. The manure from this ox is made into ‘cake’ and used for fuel. Household waste, including ash from burnt dung and wood, is collected in a pit near the house and used later to fertilize the fields. However, this is not sufficient to fertilize the whole farm and therefore they also buy inorganic fertilizers such as DAP and urea.
Case study: Ogbamichael Afewerki’s household

Ogbamichael Afewerki and his wife Letensea Ghebru have 7 children, 3 boys and 4 girls.

They planted 38 *Eucalyptus cladocalyx* in their back yard 8 years ago having obtained free seedlings from Abardae state forest nursery. During our visit, we found the young trees had reached an average height of 2.5 m and were 3–4 cm in diameter at breast height. The objective of planting the trees, according to Letensea, is the production of firewood, construction poles and shelter. Shortage of firewood is a serious problem in the household. The wife and her small children collect animal dung and crop residues from the fields for household fuel, which contributes to the depletion of soil fertility. They also have a kerosene stove and use 5 litres of kerosene each week.

The family own 5 sheep whose manure is collected in a shallow pit dug in front of their *hidmo*. Each year, they take this manure to the fields to enrich the soil. However, this is not enough for the 0.6 ha of farm land that the family owns. Thus, they also buy 50 kg of inorganic fertilizer, mainly DAP. The major crops grown are sorghum, barley and maize; the yield varies from 500–1,000 kg in a good year to less than 300 kg in a poor year. This is not enough to feed the whole family, however, so the father also works as a mason during the agricultural off-season.

Constraints

- There are frequent termite attacks on the planted seedlings and thus some of them die before reaching maturity.
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- Animal dung and agricultural residues are collected from the fields to supply household energy, thus contributing to soil depletion.
- Roof-water harvesting is not a common practice in the village, but some people divert some roof water to their homestead woodlots.
- All villagers are allowed to cut and collect *Acacia etbaica* three times a year for firewood. This will eventually lead to elimination of the remaining woodland.

**Recommendations**

- Other woody species, especially fruit trees and climbers such as *Casimiroa edulis*, *Prunus persica*, *Cordia africana* and *Vitis vinifera*, should be planted to provide supplementary food for families.
- Small-scale poultry enterprises that can be managed at household level could benefit from the shade of trees and could generate extra income.
- Development of agroforestry, especially planting trees on farm boundaries and on soil-conservation structures, could provide fuelwood and construction poles and act as windbreaks. If leguminous species are planted, they could contribute to soil improvement and agricultural production. Problems may arise, however, since the existing dessa land-tenure system does not provide security of tenure for such agroforestry investments. However, under the new land laws, a farmer will be compensated for any permanent structures or woody perennials if the land is subsequently allocated for other purposes.
- Each household should construct a tank, either below or above ground, to harvest water from roofs. Using such water could help the development of multistorey homegardens around farmers’ homesteads.

![Figure 8: Ato Ogbamichael Afewerki’s homestead woodlot, Kitmewli village.](image-url)
SKILLS REQUIRED

- Knowledge of methods of termite control.
- Knowledge of roof-water harvesting.
- Knowledge of a variety of fruit trees, their requirements, propagation, etc.
- Knowledge on how to set up and run small-scale poultry schemes.
- Knowledge of agroforestry technologies (including homegarden development) and their potential and constraints.
- Knowledge of relevant land-use systems and resulting implications.
- Knowledge of above- and below-ground water-tank construction.

6. AREAS SURROUNDING PONDS AND DAMS

6.1 The case of Lamza

Introduction
Lamza is located about 8 km south of Asmara in the Makel Zone, Galanethi Subzone, at about 2,150 m altitude. The area is accessible by a dry-weather road and thus farmers have easy access to a market for their agricultural produce. The climate is mild with a rainy season from June to September and an annual rainfall of about 500 mm.

Lamza can be divided into three main areas: plateau, valley and the escarpment. The plateau of slightly stony black-cotton soil is very suitable for agriculture, which is rainfed. The valley is long and narrow and a medium-sized river runs through it. The soil is sandy and susceptible to erosion. There is a small dam at the upper end of the valley which supplies water for irrigation. The escarpment is very steep with little soil and thus is not suitable for agriculture.

Lamza village is relatively small with about 120 households. It is located in a flat area in the middle of the escarpment, so the farmers have to descend about 60 m to the irrigated fields in the valley.

Lamza is well known for its high-quality vegetable production and for its relatively efficient utilization of available irrigation water. The farmers in Lamza are very successful, and this success is attributed to the efficient water-user organization.

Vegetation
The natural vegetation of Lamza had been carefully managed and protected, but
Unfortunately most of it was destroyed by Ethiopian soldiers in 1989–1990. After independence, the area was put under a closure and as a result there is now some regeneration.

Grazing and firewood collection are done in a manner that does not harm the natural vegetation. In order to avoid overgrazing, farmers are not allowed to keep more than 1 donkey, 2 oxen and a few sheep. They are also allowed to collect a certain amount of firewood, but only three or four times a year.

The natural vegetation includes:

- *Olea africana*
- *Euphorbia abyssinica*
- *Euclea schimperi*
- *Maytenus senegalensis*
- *Rumex nervosa.*

There is also a Government-sponsored programme of afforestation with eucalyptus planted on hillsides.

**Land tenure**

Land in Lamza is communally owned. Every 5–10 years, the land is redistributed equally to the farmers. It is permissible to rent land to another farmer from Lamza, but only old people do this.

The total area of irrigated fields allocated to each farmer is about 200 m² divided into three plots at three different locations.

**Agricultural practices**

The irrigated crops at Lamza are vegetables like spinach, cucumber, carrots, tomatoes, onions, potatoes, cabbages and lettuce. The area is known for the high quality of these vegetables, most of which are grown throughout the year.

Each farmer grows his own seedlings, mostly from seeds purchased in a market. A seedbed is prepared in one corner of a field; but generally farmers lack experience in proper nursery management, thus the seedlings tend to be poor quality.

All field operations such as ploughing, weeding and cultivation are done by manual labour. Most farmers perform these operations properly and all the fields are well maintained. However, there is a shortage of farm implements.

All of the irrigated fields in Lamza are terraced with bench terraces made of earth or stones and covered with grass. The terraces are well maintained, partly because the grasses grown on them are well established because of the availability of irrigation water. Damaged terraces are repaired very quickly otherwise this may affect the irrigation system. Thus erosion in the fields is minimal or non-existent.

Animal manure is the only type of fertilizer used and the fields are manured after every harvest. However, because farmers are only allowed to keep a few animals, there is a general scarcity of animal manure and the rate of application
is very low. Crop residues are left on the ground and later ploughed under. Judging from the stand and vigour of the vegetables in the field, however, the fertility of the soil can be rated as fairly good.

**Irrigation**

The small earth dam that supplies the irrigation water has a capacity of about 150,000 m$^3$. It was constructed in 1981 and is the only source of water for irrigation in the area. There is one motorized pump used to draw water for the whole village, i.e. serving an area of about 5 ha. Seepage water from the dam and excess irrigation water is collected in small holes and also used for irrigation. A bucket is used to draw such water.

Furrow irrigation is the most common system of irrigation for the vegetable fields, each of which is about 80–100 m$^2$. Border irrigation is also practised for vegetables like carrots, spinach and onions. The beds are 8–14 m$^2$ and the furrows are made very short (1–3 m long).

All canals are open earthen canals, not properly aligned or constructed, and many weeds and grasses are allowed to grow in them. The canals do not have proper flow-control structures, but the water flow is controlled by blocking the canals with soil.

Most of the fields are irrigated in a continuous rotation. Every day, the water-users’ committee assigns two farmers to irrigate specific fields. This means that each individual farmer does not have to worry about when he can irrigate his own fields. However, in the case of those fields irrigated from excess water using buckets, the individual farmer is responsible only for his own field and is free to irrigate it whenever he chooses.
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Water management

The strong water-users’ committee in Lamza is elected every year and decides how water should be allocated and any other matters concerning irrigation. Water ‘laws’ are well respected by the farmers. Available water is shared equally by the users, and if a shortage is anticipated the committee decides to eliminate selected fields in such a way that the adverse effects are suffered by all farmers equally.

Case study: Tekle Berhe

Tekle Berhe is 38 years old and married with two children. He owns three irrigated fields with a total area of 220 m² and rents another 200 m² of land at a cost of 500 Nakfa per year. He spends most of his time working in his fields. Two-thirds of his fields are irrigated by the communal village water pump. The other third is irrigated by drawing water using a bucket. The fields are irrigated every 4–6 days and his wife helps him with weeding and cultivation. Tekle grows a variety of vegetables and transports them to Asmara market by cart or donkey. His yearly income is about 5,000 Nakfa. Tekle thinks he could manage a larger area than he now has but it is not easy to obtain additional fields to rent.

Conclusions

The success of Lamza’s farmers is due to the existence of an efficient water-users’ committee. The farmers are well organized and disciplined in the use of the available water. The irrigation system at Lamza is relatively efficient and makes the farming profitable. Further increases in production can be achieved by increasing the irrigated area.

Recommendations

- Introduction of a lined and properly constructed canal system, installation of water-control structures, and levelling to increase the furrow length.
- Profits could be increased by establishing a marketing co-operative.
- There is a need for extension activities to introduce a better system of production, e.g. for improved seedlings.
- Provision of credit facilities to enable farmers to buy agricultural implements which are in short supply.

SKILLS REQUIRED

- Design of small-scale irrigation schemes.
- The ability to facilitate formation of water-users’ committees.
- Knowledge of vegetable seedling production and vegetable production generally.
- The ability to give advice on credit and marketing cooperatives.
6.2 The case of Adi-Absha

Introduction
Adi-Absha is about 23 km west of Mendefera town in the Debub Zone, Emnighaili Subzone. It is accessible by a dry-weather road which is in fairly good condition throughout the year.

Most of the land in Adi-Absha is very rugged with steep hills that are not suitable for cultivation. The hills are separated from each other by very narrow but moderately sloping valleys where most of the agricultural activities are concentrated, though the soils are very shallow and stony. There is one long and narrow valley, which is also cultivated. At the upper end of the valley, there is a dam constructed in 1996 for irrigation purposes.

Adi-Absha is hot and dry for most of the year. The average annual temperature is 17–21°C. The main rainy season is from mid-June to September and the average annual rainfall is about 500 mm (Mendefera Meteorological Station).

Originally, the land-tenure system in the area was what is called ‘tzelmi’, which means individual ownership of the land. This system had been practised for many years, but about 15 years ago the dessa system was introduced. Formerly, only married male members of a village were allowed to obtain land, but now all members of the village over the age of 18 are eligible.

Vegetation
Some dominant species in the vegetation of Adi-Absha are:
- Dodonaea viscosa
- Euclea schimperi
- Acacia etbaica
- Acacia nubica
- Juniperus procera
- Cynodon dactylon (grass)
- Pennisetum spp. (grass)
- Hyparrhenia spp. (grass)
- Rumex nervosa.

Until very recently the area was covered with dense vegetation, but now it is one of the most denuded parts of the zone. This is the result of uncontrolled human interference. Trees have been cut either for firewood or to acquire land for cultivation. Much devastation was also caused by the former Ethiopian troops cutting trees for sale.

After independence in 1991, most of the degraded land was put under a closure with restrictions on grazing, farming and firewood collection. As a result, the natural vegetation is now regenerating.
Agricultural activities

The agricultural system in Adi-Absha was a mixed one with both crop and livestock farming, but with greater emphasis on livestock production since much of the area is unsuitable for cultivation. However, because of drought, the number of livestock in the area decreased drastically and farming then became the dominant activity for most families.

Thus, soil-conservation activities were started only a few years ago and do not seem to be well understood by the farmers. Most farmers cultivate very steep areas without constructing terraces, which has resulted in soil erosion. The few terraces that exist are neither properly constructed nor maintained and often do not follow the contours.

Few farmers apply manure to their fields, although its effect on crop yield is well understood.

Irrigation

A dam with a capacity of 1.1 million cubic metres of water was built in the area in early 1996. Its purpose was to supply water for irrigation as well as for drinking, but irrigation was not begun until mid-1997 because of:

- Lack of previous irrigation experience among the farmers
- Absence of effective Ministry of Agriculture extension programmes for training farmers
- Lack of a water-users' organization to make decisions and manage the operation of the dam and the sharing of its water.

Figure 10: Harnet dam in Adi-Absha.
In spite of these constraints, a few interested farmers have managed to start irrigation in the area below the dam. At the end of 1997, these farmers took the initiative to buy a motor pump and started irrigation.

However, no irrigation-layout plan has been prepared. A few inexperienced farmers simply obtained motor pumps and began irrigating scattered fields using seepage water from the dam. There are now three pumps serving about 15 farmers. A large hole is dug to collect seeped water which is then pumped for irrigation. As the number of users increases, shortage of water is becoming a very serious problem, while the dam is always full and provided with an irrigation outlet so that farmers could irrigate using gravity. Opening the dam outlet gate could solve this water-shortage problem, but a management system for the dam has not yet been established.

Neither is there a defined canal system; some farmers use open earthen canals and others use pipes. Erosion is severe. The furrows and basins used for growing vegetables and some fruit are not regular or well defined and irrigation efficiency in the area is probably one of the lowest in the country.

Normally each farmer has about 0.15 ha that is suitable for irrigation. An arrangement is made between the pump owners and other farmers such that the pump owners provide fuel, water and seed, and the land owners provide their land and labour with the yield being shared equally.

Since irrigation was only introduced in the area one and a half years ago it is too early to assess the vegetable farming and cultural practices. Crops such as tomatoes, peppers, onions and fruit like pawpaw and banana have, however, been tried and seem to do well. There is no nursery, thus each farmer grows his own seedlings which are of poor quality. Weeding and harrowing are done well and by hand.
Case study: Girma Mengis

Girma Mengis has no previous irrigation experience. When the dam was constructed in 1996, he was looking forward to owning a water pump and starting an irrigated farm. He was able to purchase a 12 HP pump from the marketing section of the Ministry of Agriculture on a credit basis.

Girma has been allocated about 0.15 ha of land for irrigation just below the dam. He dug a large hole adjacent to the dam to collect water seeping out of it. He also arranged the irrigation of about 1 ha of land with 7 other farmers on a crop-sharing basis. With this arrangement, a pump owner provides water and seed and the landowner provides the labour required, with the produce being shared equally between them.

Girma grows tomatoes, red peppers, onions and potatoes. However, because of his lack of experience, yields of all these crops are low. The crop-rotation cycle followed is tomato–onion–potato–red pepper, but this is not yet a well-established practice. No fertilizers are applied, but Girma said that in the future he will try to buy manure or other fertilizers such as urea and DAP because he believes this could increase his yields.

Conclusion

To introduce irrigation in areas where farmers have no previous experience, very effective extension work is needed. But this is not available in Adi-Absha, thus the introduction of irrigation has not been very smooth or effective.

Figure 12: Adi-Absha; inefficient water distribution because of a lack of proper water-control structures.
Recommendations

The following recommendations are made:

- Introduce irrigation techniques through effective extension work and establishment of a demonstration farm.
- Agricultural implements are in short supply. The Ministry of Agriculture should make credit available to farmers.
- Assist farmers to establish water-users’ organizations that will manage the dam and the distribution of irrigation water and other matters of common interest.
- Technical assistance is required for initial preparation of the irrigation structures.

SKILLS REQUIRED

- Design of small-scale irrigation, including dam management.
- The ability to facilitate formation of water-users’ committees.
- Knowledge of vegetable seedling production and vegetable production generally.
- The ability to give advice on obtaining credit.

6.3 Conflict between irrigation and grazing land: the case of Adi-Shumale and Adi-Yakulu dam site

Adi-Shumale and Adi Yakulu villages are located in the Debub Zone, Emni-haili Subzone about 25 km southwest of Mendefera, the capital of the Southern Zone. The dam, which is under construction, is located between the two villages on the Maidagude seasonal stream. The water catchment area is about 8 km², the capacity of the dam is about 400,000 m³, and there are about 40 hectares of irrigable land.

The main objective of the dam is to harvest water for more crop production. The beneficiaries are the villagers of Adi-Yakulu who have all the irrigable land below the dam, while the land around Adi-Shumale cannot be used for irrigation as it is the catchment area for the dam.

This unequal share of the benefits of the dam between the two villages has resulted in conflict as grazing land was taken from Adi-Shumale for the construction of the dam and for the area closure for the catchment. A substantial piece of land was taken from the village out of which about 40% was cultivable and about 60% for animal grazing and browsing. Since all Adi-Shumale’s land is located above the dam, they do not get the benefit of the dam for irrigation and are demanding a share of the irrigated land as compensation, or alternatively to be allocated other land. This has resulted in some animosity, but the dam site implementing agency has not been able to resolve the matter and the case remains pending until the Land Proclamation No. 58 of 1994 is fully implemented.

Although Adi-Shumale farmers are allowed into all the protected areas to use the grass by the cut-and-carry method, few farmers are familiar with the
method and are still violating regulations by allowing their livestock to graze on the protected area at night. This is an indication of too hasty decision making before a detailed study was carried out of grazing capacity of the area in relation to the number of livestock in the village.

**The construction of the dam**

The area closure was implemented at the same time as the construction of the dam. In principle, area closure should be implemented at least 2–3 years prior to the construction of a dam. This would give time for sufficient regeneration of the vegetative cover to control the soil erosion, which would result in siltation of the dam and shortening of its life span.

**Constraints**

- Lack of attention to possible conflicts between villages as a result of area closure for dam construction.
- Delay in compensation in the form of allocation of alternative land to the villages losing land to the dam project.
- General shortage of grazing land.
- Lack of awareness of the advantages of cut and carry.

**Recommendations**

The following recommendations can be made:

- A detailed study should be carried out prior to the implementation of an area closure. Hasty decisions on area closures may result in overgrazing of other open areas.
- Closure of an area should be implemented 2–3 years prior to construction of dams in order to give more time for vegetation to recover so as to minimize sedimentation.
- Potential conflicts that may arise from closure of an area should be determined and solved before the implementation of the closure.
- Ways of sharing the benefits of the dam between the people of the two villages should be worked out.

**SKILLS REQUIRED**

- The ability to analyse the socio-economic consequences of interventions such as area closures and dams.
- The ability to act as a mediator in situations of conflict between different groups.
- The ability to assess the consequences for livestock carrying capacity when area closures are planned in different areas.
7. RIVER-BANK STABILIZATION

7.1 The case of Haicota/Gash river bank

Introduction

Haicota is located in Gash-Barka Zone, along the Barentu–Tessenei road 70 km from Barentu on the Gash seasonal river. It is in the southwestern lowland zone characterized by a hot and arid climate with temperatures ranging from 21 to 41°C. The mean annual rainfall recorded from the nearest meteorological station at Tessenei is 200–400 mm, and is very erratic, i.e. distribution both between seasons and within a rainy season is very uneven. Uneven spatial distribution is also very evident even over small distances. The soils on the river bank are alluvial deposits, mainly Fluvisols, and in the flat areas away from the river bank Luvisols are dominant. On hilly terrain the soils are very shallow and mainly Lithosols.

Some common species in the riverine vegetation of Haicota are:

- *Acacia tortilis*
- *Hyphaene thebaica*
- *Prosopis chilensis*
- *Tamarix aphylla*
- *Ziziphus spina-christi*.

River-bank erosion

During the rainy season, the Gash river is wide and shallow with occasional flash floods. The riverine forest in the Haicota area is being cleared for horticultural development resulting in severe erosion of the fertile land. Although there is deposition of silt to form new land, river-bank erosion has severe ecological and economic consequences that could affect long-term agricultural development.

The history of irrigation

Commercial irrigated agriculture is the major land-use system on the banks of the Haicota. These riverine areas are attractive for agricultural concessions because the soils under the forest are very fertile and, although the rainfall is unreliable, surface and ground-water resources can easily be used for irrigation. This potential has been recognized for a long time and large areas of the riverine forest were cleared during the Italian colonial period, especially during the 1920s and 1930s. However, the Italian investors were conscious of the need to prevent changing the rivers’ courses and therefore used gabions and checkdams. From 1975 to 1991, most of the horticultural farms in these areas were abandoned as a result of the liberation war. This situation created the opportunity for the riverine forest to regenerate in the abandoned horticultural areas, but after independence in 1991 concessions were again allocated to investors by the Government.

Once again, the major land-use system along the river is commercial irrigated agriculture. There are now 22 agricultural investors in the Haicota area allocated a total area of 642 ha, out of which 423.5 ha have already been cleared and
developed for horticulture. The main crops grown are bananas, lemons, oranges, pawpaw, onions, tomatoes, okra and mangoes.

Soil-conservation efforts
A few commercial farmers have made attempts to stabilize the river banks, but few of them have implemented any conservation measures to stabilize the soil on their farms.

Constraints
Few investors follow the Ministry of Agriculture directives restricting clearing of vegetation within 50–100 m of both sides of a river and prohibiting cutting down of important trees even beyond that limit.

Some of the reasons why farmers clear up to the edges of river banks are:
- Lack of appropriate land-use planning
- Lack of agricultural skills and low initial capital to purchase water pumps to draw water from further away
- Lack of supervision after allocating the land to developers
- Lack of motivation for reafforestation
- Lack of appropriate studies by agricultural experts prior to land allocation
- Lack of co-ordination between different disciplines
- Failure to enforce regulations and a shortage of knowledgeable forest guards
- Lack of understanding about the hazards of river-bank erosion.

Recommendations
In order to protect river banks effectively, the following measures are required:
- The Government should pass legislation covering conservation of river banks and riverine forests. But for now, reinforcing existing directives is still important.
Only land beyond the riverine forest should be granted for agricultural concession.

Any proposed development project near river banks should first be subject to environmental-impact assessment.

Promote awareness and mechanisms for ensuring the participation of local people in combating river-bank erosion.

Encourage conservation activities in the upper catchment areas.

Allow long-term credit to horticultural investors.

Encourage investors who have already cleared 50–100 m from the river bank to replant with different species, including fruit trees, grasses and climbers.

Prepare an appropriate land-use plan emphasizing river-bank stabilization and sustainable agriculture.

Promote links between the extension service, local people and investors.

Promote research to identify vulnerable areas and prepare an appropriate plan of action for river-bank stabilization.

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**Case study: Horticulturalist Solomon Hagos**

Solomon Hagos returned to Eritrea before independence in 1990 having lived in Germany. He owns about 20 ha of land on which he grows okra, tomatoes, onions, egg plant, pawpaw, guava and lemon.

Initially, he was not aware that clearing the riverine forest could result in erosion of the river bank on his farm. He cleared the forest and is now left with only some *Hyphaene thebaica, Balanites aegyptiaca, Acacia mellifera, Acacia nilotica, Prosopis chilensis* and *Calotropis procera*. But now having been affected by river-bank erosion and flooding, he has planted *Arundo donax, Pithecellobium dulce* and *awir* (Tigre) in rows about 10 m apart and 550 m long following the river bank. The *awir* and *Arundo donax* are propagated by cuttings, but Solomon took the initiative to import seeds of *Pithecellobium dulce* and raised seedlings in his farm nursery. The seedlings have survived very successfully, and the river-bank erosion seems to have been controlled by these measures.

By contrast, the farm of his neighbour, Ibrahim Tahir, is under great threat. A well originally dug 20 m away from the edge of the river is now inside the river bed. This indicates that much valuable arable land has already been washed away. Unless great reclamation efforts are made, his investment will be lost and his activities may even negatively affect the adjacent farms.

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**SKILLS REQUIRED**

- Awareness of the importance of riverine vegetation.
- Knowledge on suitable species for planting along river banks, including propagation techniques.
- Knowledge about the appropriate rules and regulations.
- Knowledge on techniques of gabion construction.
7.2 The case of Akordet/Barka river bank

Introduction
Akordet is along the main Asmara–Barentu road 140 km from Asmara in Gash Barka Zone. It is in the northwestern lowland zone and has a hot and arid climate. Rainfall ranges from 150 to 400 mm per annum and the temperature from 15 to 45°C.

The soils along the banks of River Barka are alluvial deposits, mainly Fluvisols, and in the flat areas further away from the river mainly Luvisols. In the hilly areas, the soils are shallow and mainly Lithosols.

Common species in the riverine vegetation are:
- *Acacia tortilis*
- *Hyphaene thebaica*
- *Ziziphus spina-christi*.

Some species in the flat and undulating areas are:
- *Acacia tortilis*
- *Cadaba rotundifolia*
- *Capparis decidua*.

The farming system
Farming along the Barka river adjacent to Akordet is mainly based on small-scale irrigation. There are 86 investors in this area who have been allocated 816 ha, out of which 532 ha are already planted with different horticultural crops. Bananas are dominant, covering 325 hectares, and other minor horticultural crops are onions, tomatoes, mangoes, lemons, oranges and guava.

Soil erosion along the river banks
Few of the horticultural farm owners comply fully with Ministry of Agriculture directives. As a result, heavy floods in August 1998 washed away 10 ha of bananas, one well and 43 pumping tubes. Local people claim that the agricultural concessions in the riverine forest area are causing conflict with traditional land use, i.e. pastoralism. In the view of the local people, clearing of forests is a great threat to the river bank. They also argue that protecting the riparian vegetation from clearing is the only remedy if the river bank is to be stabilized.

Although river-bank erosion is a result of complex environmental factors, there is little doubt that riparian vegetation plays a major role in stabilizing the banks. Once vegetation is removed, a vulnerable spot is created which is susceptible to erosion, particularly when peak floods occur. But in some cases, such biological conservation might not be sufficient without the aid of additional physical structures.

Constraints
In this area there are two nurseries, Akordet and Engerne, managed by the
Ministry of Agriculture and the Eritrean Orthodox Church, respectively, where seedlings of different species are raised. The Akordet nursery, adjacent to Akordet town along the Barka river, produced 55,618 seedlings in 1998. These seedlings have been planted on hillsides by the local people through cash-for-work and the students’ summer programme (under which school children of Grade 8 and above participate in soil-conservation and afforestation activities during their summer vacation).

Case study: Dawit Zeru

Dawit Zeru, one of the investors in a place called Brezeti, close to Akordet, said that he had left a forest block about 75 m wide along the river bank when he established his farm 4 years ago. He claimed, however, that this riverine forest alone can never protect the river bank from erosion because there is rarely any undergrowth in mature doum palm (*Hyphaene thebaica*) forest and such undergrowth is important to slow down the speed of the flood waters that cause erosion. He had planted *Arundo donax* and *Ziziphus spina-christi* to enrich the vegetation cover on the river bank within his farm, but they were washed away by the heavy flood.

Nevertheless, he is still keen to replant the area so as to protect it from erosion. He believes that gabions on the bends of the main course and where tributaries join the river would be the most effective means of stabilizing the river bank.

Out of the seedlings produced, 1,600 *Senna siamea* seedlings and 900 *Pithecelobium dulce* were set aside by the investors for planting along river banks. However, little has been done for the following reasons:
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- Investors feel that the return they get from planting trees is not as quick as that from horticultural crops
- Lack of awareness of the potential economic loss due to erosion until flooding and damage actually occur
- Doubt about the efficacy of trees in stabilizing river banks without the aid of additional physical structures
- Lack of commitment to implementing the Ministry of Agriculture directives of 1994
- Gabion construction on vulnerable spots, coupled with re-vegetation, is effective but very expensive.

Recommendations
In order to protect river banks effectively, the following recommendations are made:

- The Government should pass legislation on the conservation of river banks and riverine forests; for the time being, enforcing existing directives is still important
- Only land beyond the riverine forest should be granted for agricultural concession
- Any proposed development project near the river banks should be subject to environmental-impact assessment
- Promote awareness and mechanisms for ensuring the participation of local people in combating river-bank erosion
- Encourage conservation activities in the upper catchment areas
- Allow long-term credit to horticultural investors for gabion construction
- Encourage investors to replant river-bank areas that have already been cleared with a variety of species, including fruit trees, grasses and climbers
- Prepare land-use or farm plans that take river-bank stabilization into consideration
- Promote links between extension services, local people and investors
- Promote research to identify vulnerable areas and prepare an appropriate plan of action for river-bank stabilization.

SKILLS REQUIRED

- Awareness of the importance of riverine vegetation.
- Knowledge on suitable species for planting along river banks, including propagation techniques.
- Knowledge of the appropriate rules and regulations.
- Knowledge on techniques of gabion construction.
8. ROADSIDE TREE PLANTING FROM DBARWA TO ADI-QUALA

8.1 Introduction

A variety of tree species have been planted on both sides of the road from Dbarwa to Adi-quala, a distance of 60 kilometres. The Ministry of Agriculture was responsible for the overall management and financing of the planting activities, while the local subzone administration organized the participation of the local people.

The main objectives of planting the trees were to rehabilitate the vegetation and to provide beauty and shade. The planting was done on 20 June 1995 (Martyrs’ Day) selected specifically to create awareness among the people in the hope of ensuring their full participation in planting and maintenance of the trees.

8.2 Species

The species planted were:
- *Grevillea robusta*
- *Jacaranda mimosifolia*
- *Melia azedarach*
- *Acacia saligna*
- *Schinus molle*
- *Casuarina cunninghamiana.*

Some 18,775 seedlings were planted at a spacing of approximately 5 m, depending on the species, and about 20 m from the centre of the road. The survival rate is about 90%. The planting was not designed to protect the roadsides and bridges from erosion since the trees were widely spaced and about 20 m away from the road, which is too far to protect these structures from erosion.

The roadsides and bridges are subject to severe erosion from floods during heavy rains and the situation requires attention from concerned authorities. An alternative may be to plant deep-rooted grass species such as vetiver grass, as in many other countries this grass has proved effective for stabilizing structures such as dams, canals, and roads. Vetiver grass is available in the Ministry of Agriculture Betghiorgis nursery and can be obtained on request. Other grasses, locally known as *edni* and *arghe*, are equally important for soil conservation.

8.3 Management practice

For five months water for the seedlings was supplied by individuals through the food-for-work programme. The Ministry of Agriculture provided a water tanker and each plant was fenced off and well protected against livestock. Initially, there were 60 guards to protect the trees, each guard being responsible for the trees
within a radius of 2 km. Each guard was paid 7 Nakfa per day, or 210 Nakfa per month. The seedlings were obtained from the Iyamo, Sememo, Mai-tekela and Halhale Ministry of Agriculture nurseries.

8.4 Constraints
- Roadside tree planting is very costly, especially in watering and protection.
- In some areas, the selected species are not adapted to the site conditions.

8.5 Recommendations
- Mulching, weeding and other care of the seedlings should be properly managed. Mulching is particularly important during the hot and dry season to maximize the moisture available to the plants and help reduce the need for watering. Decayed mulch is also a very important source of nutrients for the plants, and during heavy rain mulch can prevent erosion around seedlings and suppress weeds.
- While mobilizing the people for planting trees, the road authorities should co-ordinate with the Ministry of Agriculture to have planting of deep-rooted grasses on roadsides included in the programme.

SKILLS REQUIRED
- Knowledge of species of grasses and trees that are suitable for roadside planting.
- Knowledge on road design and requirements (road engineers) to be combined with the ability to assess the risk of erosion on different types of land (agriculturalists).
9. SMALL-SCALE IRRIGATION

9.1 The case of Alaa

Introduction
Alaa is in the Debub Zone, Dekemare Subzone, about 23 km southwest of Asmara. It is accessible by a 70-km tarmac road from Asmara via Dekemare.

Alaa is on a plain and has an area of about 2,000 ha. It is surrounded by mountains and the plain is intersected by many small streams and rivers. There are a few small scattered hills. The average altitude is about 980 m.

Soils and soil conservation
The predominant soils in the area are sandy. In most parts of the plain they are deep but along the base of the hills they are highly eroded, shallow and stony. In some cultivable areas, the soils have been improved by deposition of silt through spate irrigation.

Because of the high sand content of the soils, they are easily eroded by rain, and sheet erosion is the dominant type of erosion in the area. The problem is aggravated by the absence of vegetative cover. The river beds are continuously mined for construction sand.

To reduce erosion, small earth bunds have been constructed following the contour in the fields, but since there is no proper maintenance these bunds are not very effective. Orchards are properly terraced and maintained. Different-sized bench terraces are constructed, either from soil bunds or by using stones. Such terraces are very effective in conserving soil and water.

Natural vegetation
The main species in the upper areas are:
- *Dodonaea angustifolia*
- *Acacia etbaica*
- *Maytenus senegalensis*
- *Euclera schimperi.*

The main species on the flat plain are:
- *Acacia tortilis*
- *Calotropis procer.*

Currently, the natural vegetation is severely depleted. There has been acute competition for land suitable for orchards, and farmers who obtained land cleared the natural vegetation in order to plant such orchards. This resulted in disappearance of the natural vegetation, and because of drought and uncontrolled grazing regeneration has been minimal.
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Climate
The mean annual rainfall at Alaa is about 500 mm per annum, but there are significant variations so that it is often less than 300 mm per year, and there are years when there is no rain at all. The rainfall is not only scarce, but the distribution within the year may also be very irregular and because of this many crop fields are abandoned and orchard owners rely more and more on flood water for irrigation.

Agriculture
The main rainfed crops grown in Alaa are maize and sorghum. Vegetables such as onions, tomatoes and peppers, and fruits such as oranges, lemons and pawpaw are grown under irrigation. Cultivation of the irrigated orchards and vegetable fields is done manually using hoes, and is carried out 5–6 times a year, depending on the irrigation frequency.

In orchards, one sack (about 50 kg) of manure is applied to each tree per year. In addition, some rich farmers apply a mixture of urea and DAP. Manure and, rarely, inorganic fertilizers are applied to vegetable fields. The rate of application varies from farmer to farmer, but is normally lower than recommended.

All types of agricultural products are harvested manually. Cereals are threshed by trampling with oxen or donkeys.

Vegetables and fruit are protected from pests by applying chemicals bought from the Ministry of Agriculture. The application is carried out with manually operated knapsack sprayers.

Figure 17: Infertile area reclaimed by diverting spate flow, now under maize.
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Irrigation

Water shortage as a result of the erratic rainfall is the most important limiting factor for development of irrigated agriculture on the Alaa plain. Thus, production of vegetables and fruit under irrigation is becoming increasingly important and water from both wells and flood water is used for irrigation.

Each farm has one or more wells. These are hand-dug open wells without lining and are 10–25 m deep. Since there is no law regulating the use of ground water, the farmers are free to exploit any amount that is available. This creates severe competition between them and they have to continuously deepen the wells to obtain enough water.

When a farm is located near a river or stream, and if the topography allows, the spate flow is diverted directly to the fields. Enough moisture is conserved and, in addition, the sediment carried by the spate flow and deposited in the fields increases fertility substantially. This irrigation is normally carried out 1–3 times a year, depending on availability of the river flows.

Constraints

- Existing river-diversion structures are not provided with an effective mechanism for controlling water flow. The present traditional system is not sustainable technically and environmentally since it is based on the use of branches and stones which are easily broken or carried away in big floods.
- Water is diverted to different branches of the canals by blocking or opening canal entrances using earth. These are easily breached by the flow, thus making water distribution work inefficient and tiresome.

Figure 18: Once infertile rugged area reclaimed by diverting spate flow and now under fruit trees.
Soil Conservation in Eritrea: Case Studies

**Recommendations**

- Diverting flood water into a farm is recommended since it adds substantially to the fertility of the soil.
- To properly utilize flood water for crop production, fields must be provided with water-control structures.
- Earthen canals should be replaced by cement-lined canals or with pipelines.
- Improved water-diversion structures should be made that allow regulation of flow.
- Easily managed flow-control gates should be introduced.
- Strengthening earth embankments by periodically adding soil and consolidating them by planting grass such as cynodon.

**Case study: Tewelde’s fruit farm**

Tewelde owns a fruit farm in the northwestern part of the Alaa plain. It is a medium-sized farm and at present produces mainly citrus under irrigation, but he hopes to expand to vegetable and dairy production.

The natural-resource base of this farm can almost be described as man-made. When Tewelde inherited it, the land was rugged and stony and unsuitable for any kind of agriculture. But the farm is very close to Gaden river which is in spate at least twice a year, so Tewelde decided to improve his land by diverting the flood water carrying sediment from higher areas.

He started this development work by constructing a semi-permanent diversion structure on the Gaden river and an earth canal about 400 m long to let the flood water onto his land. He divided the farm itself into 0.5 ha plots and constructed approximately 1-m high embankments around each plot. He also constructed temporary intake gates.

Every year he lets flood water into the fields, and by the end of 7 years a very fertile and deep soil was created from the deposited sediments. Tewelde claimed that in some of the fields the depth of the soil increased by about 1 m.

Two big wells with diameters of 8–10 m and depths of 12 m were also constructed to irrigate the fields during the dry season. The canal systems are properly constructed and therefore very efficient.

Tewelde began planting orange seedlings in 1993, and some trees have already started to produce fruit.

According to Tewelde, the main problems on the farm are:

- In the dry season the water sources are not reliable enough for irrigation
- There are no proper structures for controlling flood water, which results in soil erosion because of the occasional heavy floods.

**SKILLS REQUIRED**

- Knowledge of irrigation techniques, including construction and maintenance of water-diversion structures, irrigation canals, embankments, etc.
- Knowledge of fruit and vegetable production.
9.2 The case of Tselima (Halhale)

Introduction
Halhale is located in Debub Zone, Dbarwa Subzone, about 8 km from Dbarwa town along the tarmac road from Asmara to Mendefera. The flat Hallale plain is about 1,825 m above sea level and is surrounded by fairly high hills on the northern, western and southern sides. The population pressure is intense, mainly because of the high potential of the area for both crop and livestock production.

Halhale is in the moist highland zone. The climate is characterized by a rainy season from June to the end of September and a few showers during April and May; the average annual rainfall is about 550 mm. The average minimum and maximum temperatures are 6°C and 29°C, respectively; the hottest month is March and the coldest months are December and January.

Case study: Kidane Kelit’s farm
Kidane Kelit farms 2 ha of irrigated land, of which about three-quarters is obtained by a contractual arrangement with 7 other farmers. These arrangements are of two types. Under the first kind of contract, he cultivates the land himself without any kind of labour input from the other farmers and then gives each of them a quarter of the resulting produce. Under the second kind of contract, Kidane only supplies irrigation water to the other farmers, and then he gets a quarter of the produce from each farmer who has received this water.

The source of water for irrigating the farm is two wells with water pumps, located about 200 m apart. The well in the southern part of the farm is very shallow and has insufficient water, but the second well supplies enough water, although the water level does fall during the dry season. The farmer uses the furrow irrigation method, but the primary canal is poorly constructed and as a result about 20% of the water is lost before it reaches the farm.

The produce is sold at Dbarwa town but the prices obtained are poor as the farmer has no time to negotiate with merchants as the produce will spoil if kept for long periods before sale. Kidane obtains his vegetable seed from Asmara merchants, but even though they are expensive their viability is not guaranteed. Kidane has begun selecting the healthiest and largest of his own potatoes to use as planting material. There is always a shortage of fertilizers and he cannot afford to buy pesticides.

Soils and vegetation
The major soil type on the flat land is deep brown Vertisols, while on the steep and undulating land both Lithosols and Cambisols occur. Except for some remnant shrubs and grasses, the natural vegetation has almost disappeared because of intensive cultivation, overgrazing and cutting of trees for firewood.
Land tenure
In many parts of the country, including the Tselima area, the land-tenure system is communal. Every piece of land in the village is classified according to its fertility, and the arable land is allocated to the members of the village according to its quality.

This system gives farmers little incentive to improve land since the rotation cycle of 5–7 years allows too little time for each allottee to reap the benefits of long-term measures such as tree planting and construction of permanent structures. In addition, crop land and grazing land are open for communal grazing in the post-harvest season, which may accelerate erosion through trampling and overgrazing. As land cannot be mortgaged or sold, the system also limits the availability of credit facilities that could be used to make land improvements.

Soil erosion and conservation in Tselima
Soil erosion in the area is attributed to overstocking. Expansion of cultivated land to meet the needs of the increasing population means that more animals are required for ploughing and less grazing land is available. Soil erosion also occurs because of trampling by animals being herded from one grazing area to another, which often results in bare paths which soon develop into gullies. Concentration of animals around water points also causes erosion.

Soil erosion is a very serious problem on steep slopes and on stream banks. Tselima is one of the most productive areas in the highlands of Eritrea, but it is obvious that the landholdings cannot be further subdivided and, therefore, in order to meet their increased needs, the people will have to extend cultivation to steep slopes which are easily eroded.
Case study: Kidane Belai’s farm

Kidane Belai farms 6 ha in the western part of the Halhale plain near the village of Imnitselim. Kidane obtains most of this land from other farmers under two kinds of arrangement. The first arrangement is on the basis of direct cash payment to the owner at a rate of 800–1,200 Nakfa per hectare per year. The second arrangement is by voluntary exchange of land. For example, land belonging to another farmer that is located near Kidane’s well is exchanged for some of Kidane’s land further away from the well. No payment is involved in this type of voluntary land exchange.

The yield of vegetables varies greatly, depending on the availability of water for irrigation and supply of fertilizers and pesticides. But average annual yields of vegetable products on this farm are:

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Tonnes/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomatoes</td>
<td>12</td>
</tr>
<tr>
<td>Potatoes</td>
<td>12</td>
</tr>
<tr>
<td>Onions</td>
<td>12</td>
</tr>
<tr>
<td>Red pepper</td>
<td>8</td>
</tr>
</tbody>
</table>

Two crops of each vegetable are grown each year and the vegetables are rotated in the following sequence: tomatoes–onions–potatoes–red peppers. He applies fertilizers such as DAP, urea and animal manure.

This farmer uses flooding as his method of irrigation, but there is substantial loss of water in the canal due to the high percolation rate. The farm is irrigated twice a week. The water is obtained from 2 wells about 3 and 10 metres deep, respectively, both with pumps. The shallow well irrigates continuously for 5 hours, while the deep one operates for 12 hours. Both the wells were dug manually and each cost the farmer about 1,300 Nakfa. The two water pumps cost 13,460 Nakfa. It is difficult to find a nearby workshop to repair these pumps in the event of breakdowns and then Kidane has to take them to Asmara. The farmer sells his produce at the town of Dbarwa, mostly at prices dictated by the merchants as he has no storage facilities for these perishable products.

Due to the existing land-tenure system, individual farmers are not motivated to construct permanent soil-conservation structures on their own plots. However, on steep slopes, some soil conservation measures such as construction of stone and soil bunds and hillside tree planting have been taken. These bunds will eventually develop into bench terraces on the cultivated lands. Bench terraces are used for two purposes aside from soil and water conservation:

- Supply of cut-and-carry grass for livestock from the terrace risers, and
- Identification or demarcation of farm boundaries.

Constraints

The main constraints facing the farmers in the area are:

- Lack of good-quality seeds
- Shortage of pesticides and insecticides
- Low market prices for vegetables
Soil Conservation in Eritrea: Case Studies

- Shortage of transportation facilities
- Lack of technical know-how on modern irrigation methods
- Lack of spare parts for motor pumps
- Lack of motor pump repair shops nearby
- Lack of storage facilities for the produce
- Shortage of land
- Lack of fertilizer and on-farm storage facilities for the fertilizer
- Lack of protection for the wells against siltation and damage
- Lack of types of vegetables that can resist frost.

Recommendations
- Good-quality vegetable seeds for small farmers should be available from the Ministry of Agriculture extension agents.
- Availability of reliable and effective chemicals should be ensured.
- Imported or local vegetable seeds should be inspected and certified by the appropriate authorities before they reach the market.
- Farmers should organize themselves to establish marketing co-operatives.
- Priority should be given to improving transportation facilities in vegetable-growing areas.

SKILLS REQUIRED
- Knowledge of vegetable production.
- Knowledge of irrigation.
- Ability to assist farmers in establishing marketing co-operatives.

9.3 The case of Mareba

Introduction
Mareba is located in Debub Zone, Segheneiti Subzone, about 57 km southeast of Asmara. It is accessible by an all-weather tarmac road from Asmara. Mareba has a total population of 1,350 in 410 households. The area is in the moist highland zone at an altitude of 2,000 m, with average annual rainfall of 450–500 mm and average minimum and maximum temperatures of 7°C and 22°C, respectively.

Topographically, it is a hilly area with gentle slopes and some undulating and flat land on valley bottoms, where most of the irrigated land is located. Some species in the natural vegetation are:
- *Aloe abyssinica*
- *Acacia etbaica*
- *Cordia abyssinica*
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- *Faidherbia albida*
- *Ficus thonningii*

The land-tenure system is a communal one with each farmer having an irrigated plot of about 450 m². Land contract arrangements are not common in this area because water is available in shallow wells and it is easy for each farmer to dig his own well. This is the main reason why there are no water pumps and almost all the 410 farm households have wells, which means that most farmers have their own irrigated plots.

**Case study: Tesfamariam Hailemichael's farm**

Tesfamariam Hailemichael has 450 m² of irrigated land as his share of communal land on which he grows cabbages, lettuce, potatoes, onions, maize, peppers and tomatoes.

The average yields of vegetables for the 450 m² are:

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Tonnes/annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabbage</td>
<td>2.0</td>
</tr>
<tr>
<td>Lettuce</td>
<td>2.0</td>
</tr>
<tr>
<td>Potato</td>
<td>0.5</td>
</tr>
<tr>
<td>Maize</td>
<td>0.2</td>
</tr>
<tr>
<td>Pepper</td>
<td>1.0</td>
</tr>
<tr>
<td>Onion</td>
<td>1.0</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.7–1.0</td>
</tr>
</tbody>
</table>

The source of water for irrigation is a hand-dug well which is only about 2 m deep and the water is hand carried from the well. The water only lasts for half an hour after being drawn and the well fills up again after 2–3 hours. Therefore, the farmer has to irrigate his land twice a day, and each bed of vegetables is irrigated every three days. During the rainy season, the land becomes swampy and is out of use until the next dry season.

Ploughing and planting are done by hand, and weeding and cultivation are carried out thoroughly. The ridges between the plots are well established and there are no signs of erosion.

The vegetables are grown in rotation as follows: cabbage–potato–tomato–lettuce–peppers–onion. If red peppers are planted on fields previously planted with tomatoes, yields are poor, therefore the farmer applies about 70 kg animal manure on the plot three times a year and 2 kg DAP twice a year.

**Soils and soil erosion**

Both sheet erosion and gullies are visible on the irrigated land, the result of flooding from an old broken earth dam located above the irrigated area. During the rainy season, the irrigated land becomes swampy and cannot be used until the dry season commences. It is likely that the dam will be entirely destroyed during a heavy rainy season, and in this event most of the fertile agricultural land may be washed away.
Soil Conservation in Eritrea: Case Studies

Constraints
The major constraints for farmers in Mareba are:
● Shortage of enough land to justify using a motor pump
● A low farm-gate selling price for vegetables due to poor marketing arrangements
● Excessive soil erosion due to flooding from breakage of the old dam, resulting in a decrease in the amount of land available for irrigation
● Lack of good seeds
● Insecure land tenure is a disincentive to making permanent land improvements.

Recommendations
The following recommendations are made:
● The old dam should be repaired to minimize soil erosion from flooding and to increase water supply
● Expansion of the area of irrigated land should be considered while repairing the dam
● Viability of the seeds obtained from merchants should be checked before they are sold to farmers
● Conservation activities in the entire valley should be considered in order to prevent soil erosion and siltation of the dam
● The Ministry of Agriculture extension agents should be more efficient in giving advice to farmers.

SKILLS REQUIRED
● Knowledge on dam construction and management.
● Knowledge on vegetable growing.
● Techniques for soil conservation on hillsides and cultivated land.
● The ability to assist villagers form marketing co-operatives.
● The ability to give advice on horticultural seeds.

Figure 20: Local-level initiative: small-scale irrigation, Mareba.
Case study: Habte Berhanemeskel’s farm

Habte Berhanemeskel has 450 m² of irrigated land where he grows various vegetables, the land having been allocated to him by the village as his share during land distribution. He grows cabbages, lettuce, potatoes, onions, maize, tomatoes and red peppers. His plot is under irrigation only during the dry season as it becomes swampy during the rainy season from June to the end of September.

The average yield of vegetables (kg/ha) is:

- Cabbage: 2,000
- Lettuce: 1,500–2,000
- Potato: 500–800
- Maize (mostly consumed when green; remainder dry): 100
- Red pepper: 800
- Tomato: 700–800
- Onion: 1,000–1,200

The irrigation water comes from a hand-dug well about 2 m deep, and the digging of furrows and water control is done manually. The main water channel is well prepared and there is not much water loss during irrigation. The vegetables are irrigated every three days. The water in the well only lasts for half an hour after being drawn and takes about 6 hours to fill up again.

The vegetables are transplanted in rows and the ridges between the rows are well prepared and clean from weeds. There are well-established bench terraces between the vegetable plots, and the grass growing on these is used for cut and carry to feed the farmer’s livestock. The farm produces two maize crops a year and the stover is also used for feeding animals.

Most vegetable seeds are bought from merchants in Asmara, but their viability is unreliable. Some farmers produce seeds themselves, but these are of low quality.

This farmer applies animal manure and inorganic fertilizers. DAP and urea are applied at a rate of 6 kg per year over the whole plot. Manure is applied for all vegetables when it is available.
10. LARGE-SCALE SPATE IRRIGATION: THE CASE OF SHEEB

10.1 Introduction

The eastern lowlands of the country are characterized by a hot and dry climate which cannot sustain any viable rainfed agricultural production. Therefore, about 80 years ago the people living there adopted a system of agriculture known as 'spate irrigation'. Throughout the eastern lowlands, the techniques used are very similar; here we take the case of Sheeb as a representative example for all the spate-irrigated areas.

Sheeb is located in the northern Semenauli Keih Bahri Zone, Sheeb Subzone, some 50 km northwest of Massawa at the foot of the eastern escarpment. The escarpment drops from an altitude in excess of 2,000 m in the highlands to approximately 200 m in Sheeb.

Sheeb is hot, arid and desert-like with mean annual rainfall of less than 200 mm falling mainly from October to April (winter rain). Mean monthly temperatures range from about 25°C in January and February to about 35°C in July and August, but with maximum temperatures often exceeding 40°C during this period. An added hazard during the summer months is afternoon dust storms and strong winds which make for a hostile and unpleasant working environment. The potential evapotranspiration is extremely high (in the region of 2,000 mm per annum), and irrigation is essential for crop production except for very occasional cultivation of drought-tolerant short-season crops such as bulrush or finger millet planted in the river bottoms.

On the eastern escarpments, the ‘small rains’ fall in April–May, and the ‘main rains’ follow in July–September causing summer runoff which feeds the spate-irrigation area in the lowlands. There, Sheeb receives its main rainfall in winter and benefits indirectly from summer rains. The flood season from July to September contributes about 65% of the annual floods, the remainder occurring from October to February, with smaller floods and reduced frequency during that period.

10.2 Soils and topography

The seasonally flooded watercourses are sandy in the alluvial plains, but adjacent to them fine sediments of considerable depth have been deposited by many years of floods. These deep soils have a high capacity for water retention. In recent times, the diversion of the river’s spate flows for irrigation has contributed to the process of deposition and soil improvement and it is thought that in much of the area soils are more than 2 m deep. Although erosion is a serious problem throughout Eritrea, it is not prevalent in Sheeb and much of the agriculture along the river is carried out on alluvial soils deposited as a result of past erosion in the highland watersheds. The spate water is very suitable for irrigation as it carries a
The irrigated areas are predominantly flat with slopes rarely being greater than 1%. There are a few gullies, depressions and areas of raised land, all caused when canals become broken.

The spate-irrigation system has been developed in the eastern lowlands as the only method of producing crops in this hot and dry area. The system makes use of short-duration spate-flood flows in otherwise dry river beds, exploiting the local deposits of deep highly fertile alluvial silts adjacent to or part of the river's floodplain. Spate-irrigation agriculture is practised mainly from September to March. Surrounding these rivers, the eastern lowlands are generally sandy, gravelly or rocky hills that are eroded and with little potential for livestock grazing and none for crop production.

**10.3 Crop production**

The yearly crop production activities are repair of broken diversion structures and canal systems, land preparation, seeding and harvesting.

*Repair of diversion structures*

Preparations for crop production commence during March and April with the rebuilding and repair of the diversion structures in the river. These are semi-permanent structures built out of sand, rocks and branches of thorny bushes. Oxen are used to haul the tree branches, move stones and boulders, and to scoop the sand into diversion weirs. These structures may be damaged or washed away with every strong flood, requiring continuous repair throughout the flood season (typically July and August).

*Repair of the canal system and earth bunds*

Once the diversion weir is in place, the diversion channels or canals are rebuilt. These structures, which are also frequently damaged or breached during heavy floods, direct the water into fields separated from each other by soil bunds. Fields receive an annual addition of silt and thus the bunds may need to be raised and/or repaired each year. An earth scoop drawn by a pair of oxen is used to do this work, which is done almost every year.

*Land preparation*

When flooded fields start to dry, large cracks form in the soil and the moisture in the soil begins to evaporate. To prevent this loss of soil moisture through the cracks, the fields are ploughed and large soil clods broken up by dragging tree trunks or branches over the field. This loose and finely broken up soil then acts as a blanket on the field reducing water loss by evaporation.
Crops

Seeds are planted in rows. A simple wooden pipe is attached to the plough and the seed dropped to the ground through this. The main crop is sorghum, which is well adapted to growing in areas with residual soil moisture as it has a deep and well-branched rooting system. This plant is efficient at extracting moisture from drying soils and can withstand limited waterlogging. The sorghum varieties grown near the river beds are tall and can be harvested either as green fodder for livestock or left to produce grain. A common practice is to plant the crop densely during September and then use the thinnings for animal feed in November. When soil-moisture levels permit, a second harvest of grain can be obtained from the same plants by ratooning. Minor crops are maize, pearl millet, finger millet, watermelon, sesame, groundnut, haricot beans, cotton and vegetables (tomatoes, okra, chillies and onions). When the floods have been good and soil-moisture levels are high, maize is often planted following harvest of the first sorghum crop. This change to maize is taking place because farmers usually get more grain from the maize crop than from a second sorghum crop. This may be attributed to a disruption of the insect build-up by rotating crops and less bird damage to maize than sorghum.

Fertility maintenance

Manuring is not practised in Sheeb. The reasons for this are:
- The flood water carries with it soil sediments and many nutrients which increase the soil fertility
- There are few livestock in Sheeb, thus manure is not available. Besides, there is no tradition of collecting manure.
Weeding
The spate flow carries with it many different weed seeds. Therefore, unless these weeds are destroyed during ploughing, there is a heavy infestation of weeds in the fields. Crop fields are neither weeded properly nor harrowed, but the weeds are left to grow and used for animal feed. Therefore, weeding is only carried out when farmers want to feed their animals. However, the dense planting of sorghum also suppresses weeds.

Harvesting
Crops are harvested and threshed by hand. The harvested crops are first left to dry completely and then threshing is done by beating with a large stick. The sorghum crop is stored either in woven containers or in sacks. With no control of insect pests, post-harvest losses can be as high as 25%.

10.4 Detailed description of the system
Agriculture in Sheeb and elsewhere in the eastern lowlands is dependent on irrigation by diversion of river-spate flows, and very little use is made of ground water for irrigation.

The principal objective of the spate-irrigation system is to divert and control sufficient water to flood the fields to a depth of up to 0.5 m. This water soaks into the deep soil and provides the residual moisture on which the crops survive. Several floods and soakings are necessary to fully exploit the water-holding capacity of the soil.

A traditional spate-irrigation network typically covers an area ranging from 100 ha to more than 4,000 ha. The farmers construct 1–3-m high temporary
embankments, known as *agum*, across the river channel upstream of the primary canal intakes to divert the low-spate flows to adjacent cultivable areas. These embankments are made from material scraped up from the river bed, reinforced as necessary with stones and brushwood. There is seldom provision for a spillway and, as the flood rises, the earth embankment is either deliberately breached or fails due to over-topping or piping through the embankment. The embankment is partially or completely washed away.

The *agum* is rebuilt, but how soon this can be done depends on the interval between consecutive river flows and the availability of draught power. Thus, the embankment cannot always be rebuilt before the next flood.

The primary canals, known locally as *musqa*, taken off from the river, have a large capacity in relation to the area irrigated because of the short duration of the spate flows. The primary canals are subdivided into smaller canals as they reach the irrigable area and farmers exercise traditional forms of priority and control so that the higher lands receive water first.

There are no permanent structures for the control and distribution of spate flows within the canal system; normally the flow is diverted by blocking the canals and distributors with temporary earth bunds and breaching them when irrigation demands are met. The irrigation water is distributed on a field-by-field basis with the basin bunds being over-topped or breached once an adequate depth of water has been applied to each field.

The traditional structures are relatively cheap to build, but require a considerable amount of maintenance during the irrigation season. If only small or medium spates occur during the season, the embankments can be very effective, but larger spates can result in the expenditure of much effort or cash with very little benefit as the diversion embankments may be completely swept away. Thus, the probability of achieving effective and regular irrigation of the whole area is low.

**Operation and maintenance**

Each field is about 0.25 ha, and 10–20 fields are grouped into a block. Each block in the canal system is irrigated independently.

Water allocation is dealt with by the Village Council (Baito or Mezabaya) and is intended to ensure an equitable distribution of water throughout the area. Nevertheless, within the irrigable area, plots nearest to the path of the water are watered first and higher ground is watered before lower ground. Traditional forms of water control are still practised, entailing diversion to the highest fields by means of a temporary check bund across the canal.

Once the highest field in a block has been filled, one of the field bunds is breached and the water flows across the top field to fill up the next basin in an ordered succession of fields. No field can obtain water until the one preceding has taken its quota. Ideally, only when every field in a given block has received water is the main canal check bund breached. The flow then continues down to
the check bund commanding the next 10–30 ha block of fields, and so on, until
the entire spate flow is dissipated.

In the past, the construction and replacement of the embankments and
distribution of flow through the canals were communal activities organized by
the farmers. Costs, usually paid in kind, were shared on the basis of benefits
received, which depended on the area of land irrigated per participant, as well as
its elevation and proximity to the irrigation supply. In the past, extensive use
was made of animal power, but as a result of the war, livestock have been so
depleted that farmers are unable to carry out these activities without external
assistance. At present, therefore, farmers are being paid to carry out maintenance
work under a Government sponsored cash-for-work programme.

Case study: Ahmed Farha

Ahmed Farha is about 48 years old, married and the father of three children. Ahmed
had spent most of his life in Sheeb, but because of the war he was forced to
abandon his 1-ha farm there and flee with his family to the Sudan. After living in the
Sudan for five years, he decided to come back to Sheeb and occupied his farm
again.

Because he lost all his livestock, he gets credit from the Government and also
some help from his relatives, and has managed to buy a donkey, an ox and three
milking goats.

When he returned to Sheeb, he found his farm totally destroyed. He then had to
construct bunds around the fields so that they could hold water. Initially, he obtained
draught animals from friends to prepare his field for planting. Since then, because
he has only one ox, whenever he wants to plough, repair or maintain his field bunds
or canal system, he must share the ox with another farmer or hire one.

His yearly routine is as follows. Before the arrival of the first spate flow, he
participates in repairing or building of the main diversion structure and canal
systems. (It is compulsory for every farmer in Sheeb to participate.) This may take
about 2 months. When the flood comes, he waits for his turn and then makes sure
that his field is properly irrigated. He must make sure that his irrigation system is
functioning properly throughout the season, as even a little negligence in this work
could cost him an entire year’s production. When his field is properly watered, he
prepares the field for sowing by ploughing it once or twice. After the crop is planted,
he spends most of his time protecting the field against animals and birds. He does
not weed or harrow, but when the sorghum or weeds grow sufficiently to be thinned
or cut he begins to feed the weeds to his animals.

When the crop is ready for harvest, Ahmed, his wife and son cut the sorghum and
prepare it for threshing. They also collect the straw and take it to their home to
store as animal feed. In good seasons, Ahmed obtains about 1.6 t from his 1 ha.
He could plant maize as a second crop during the short rains, or he could take a
second ratoon sorghum crop, but Ahmed says, because of drought and the difficulty
of protecting the crop from animals, he prefers to participate in cash-for-work
activities instead.
10.5 Constraints

The major problems faced by spate-irrigation farmers in Sheeb are:

● The uncertainty of irrigation, i.e. the probability of occurrence of floods, their magnitude and frequency are unpredictable
● The risk of large floods washing away canal intakes and head reaches, and consequent loss of command
● The high cost of maintenance as a result of frequent destruction of the diversion embankments by spates
● The traditional distribution system also lacks adequate control structures; field-to-field irrigation results in erosion and uneven field elevation because there are no spillways between individual fields and this results in considerable variability in the depth of water applied
● The high cost of permanent diversion weir- and flood-protection works, which can, however, be justified by the tangible benefits
● A general lack of knowledge on the part of the farmers of appropriate development concepts and the specific characteristics of spate irrigation and traditional water rights
● A lack of adequate provision for operation and maintenance after completion of river improvement works.

The combined result of these constraints is that the present system is inefficient in use of the available water. Often heavy floods occur at the beginning of the season and wash away the diversions. By the time the diversion is repaired, which might take several weeks if the river continues to flow, much of the available water has passed away downstream and part or all of the irrigation season is lost.

10.6 Recommendations on improvements to traditional spate irrigation

From observations of the spate-irrigation system elsewhere, the best years, in terms of area irrigated, are those when below-average runoff occurs because then farmers are able to control the flows. Thus, it can be concluded that if flows could be delivered to farmers in a controlled manner, the volumes diverted and areas irrigated each year could be considerably increased and better use made of the available water. This can be achieved by introducing relatively simple improvements to the traditional systems, including:

● The provision of permanent structures to divert and regulate spate flows from the main river to replace the existing traditional agum, with arrangements for the exclusion of unwanted sediment from the main canals and to allow the larger destructive floods to pass downstream
● The provision of permanent offtake or division structures on the main canals replacing the existing traditional structures, to divide flows into manageable
proportions and to reduce the risk of canal degradation and temporary or permanent loss of command

- The provision of secondary and field-level structures to permit greater control within the system, to improve application efficiencies and to make better use of the available water, and
- Training of river courses and bank protection to reduce the risk of bank erosion and temporary or permanent loss of command area.

The volumes of river water diverted and areas irrigated could often be doubled or trebled by installing a permanent weir at the headwork of a spate-irrigation system.

**SKILLS REQUIRED**

- Knowledge on all the techniques involved in the spate-irrigation system.
- Knowledge on methods of river-bank protection in lowland areas with flash floods in seasonal rivers.

11. PASTORAL LAND USE: CASE STUDY OF SAWA

Some of the materials presented here are taken from the papers presented to the consultation workshop on ‘Pastoralists, Land and State in Eritrea’ held in Keren, 9–11 May, 1996.

11.1 Introduction

Sawa is located in the southwestern lowlands in Gash-Barka Zone, Forto Subzone, about 70 km northwest of Akordet and is accessible by a dry-weather road.

The whole of Sawa is a flat plain through which the Sawa river flows—and given its name to the area. The altitude is about 600 m and there are a few small scattered hills. The soils are sandy with low fertility. In the riverine areas, the soils are formed by silt deposition from successive floods and are usually very fertile sandy loams.

The dominant tree and shrub species in the riverine areas are:

- *Acacia mellifera*
- *Acacia oerfota*
- *Acacia tortilis*
- *Hyphaene thebaica*
- *Cadaba rotundifolia*
- *Calotropis procera*
- *Capparis decidua*
Away from the river, the natural vegetation is sparse and acacias are the dominant species.

In general, the climate of the western lowlands is hot and dry for most of the year. The rainfall, when it does occur, is torrential, of short duration and erratic. Thus, this area generally sustains pasture for a period not exceeding 3–4 months in a year and drought severely affects most of the browse trees, grasses and livestock. Sawa has experienced many drought-related disasters in the past, and this, combined with three decades of war, has greatly diminished the resource base. Agricultural expansion, bush fires, demand for fuelwood and overgrazing are some of the other factors which have caused degradation of resources in these rangelands.

River Sawa, which is seasonal, is the only water source for humans and livestock. There are no natural permanent surface-water bodies, and the groundwater resources are also limited or difficult to exploit. The underground flow of the river is exploited by digging shallow wells in the river bed.

11.2 Traditional control of grazing

One of the reasons for the degradation of resources in the pastoral areas is the reduction in or elimination of traditional methods of controlling use of the range practised by the pastoralists themselves. For centuries the pastoralists had been living in and using these arid and ecologically fragile rangelands without causing any major damage to them. They developed methods and regulations for using this natural resource in an ecologically harmonious fashion. Seasonal migration or nomadism is one of the main strategies developed by pastoralists. Many pastoral communities evolved systems not only for controlling the usual seasonal migrations, but also for using the resources in times of adverse climatic conditions. For example, in the Upper Barka region there was a traditional pastoralist council known as Seb Gomat and scouts called Tauray whose main duty was to assess resource conditions and decide livestock movements.

But these traditional systems were unable to work efficiently with outside interference. For example, in the case of the Upper Barka region, the interference of successive commercial farmers in the communal and free-grazing land-tenure system undermined the authority of this traditional system.

11.3 Agricultural expansion

The expansion of agriculture into these arid and marginal rangelands can also be a cause of resource degradation. Farmers can cause degradation by clearing of vegetation, burning, failure to practise proper soil-conservation techniques,
rotation and fallowing. As a result of these practices, the vegetation cover is removed and the soil loosened and exposed to wind and water erosion. The overall effect of this is, of course, environmental degradation.

In the western lowlands of Eritrea, where most of the pastoral areas occur, there are few farming activities. But in the late 1950s, agriculture spread, particularly into the fertile riverine areas where there are now many small-scale farmers and agricultural concessionaires. These areas are very important dry-season grazing, but are now being taken over for horticultural activity.

Most of the commercial farming in Eritrea is irrigated and situated in a narrow belt along the major river systems of the western lowlands, that is, the Gash, Barka and Sawa rivers. Some rainfed commercial farming for sesame, cotton and sorghum is also practised in areas outside the riverine zone, but not to the same extent as before the early 1970s.

Since liberation, commercial farming activities have revived. The Government of Eritrea is encouraging development of commercial agriculture by offering land concessions on long leases at a nominal cost in an effort to revitalize the national economy. Up to the end of 1997, new leases on land totalling more than 11,000 ha were made to private investors, and applications covering another 110,000 ha were under consideration. The concession areas are mainly in the western lowlands, including Sawa.

11.4 Other factors

Bush fires
Bush fires cause extensive loss of cover, expose the soil to erosion and affect other factors which, in turn, also lead to soil degradation. However, bush fires are not as serious a problem in Sawa as in some other parts of the western lowlands of Eritrea, although there have been a few fire incidents in the past.

Fuelwood exploitation
About 90% of the energy used in Eritrea is derived from biomass, mainly fuelwood. A large proportion of this fuelwood comes from the western lowlands, including the Sawa area. This has contributed to the depletion of the acacia woodlands.

Overgrazing
According to some specialists, overgrazing is not a serious problem in Sawa since livestock numbers were significantly reduced by the three decades of war and recurrent droughts. But there is some evidence of overgrazing in the riverine areas.

11.5 Impact on the pastoral production system
These riverine areas of the western lowlands traditionally served as dry-season grazing for the majority of livestock in the country. Therefore, there will be stiff
competition between livestock owners and the expanding commercial farming. With this in mind, it is not surprising that the pastoralists in the western lowlands do not welcome the rapid expansion of commercial farms in their traditional dry-season grazing areas. The pastoralists object to the commercial farming enterprises because:

- They will be deprived of their traditional dry-season grazing resources
- The livestock will be cut off from access to watering points in the river beds
- The traditional routes to the dry-season grazing areas are being blocked
- The riverine forest resources will be depleted.

Because of the expansion of commercial farms, much of the riverine forest vegetation is being depleted and this could lead to further environmental degradation. In addition, if this expansion is left to continue, it is to be expected that within a few years most of the river banks will be occupied, also adversely affecting the pastoral production system.

11.6 Areas of potential conflict over resources

When resources are scarce, and there are competing resource users, there is bound to be a potential for conflict over the resources. In the western lowlands, the main competing resource users are the pastoral and agro-pastoral people, subsistence farmers and commercial farmers. Now returning refugees have added to this competition.

11.7 Risks

It is evident that the impact of the expected resettlement by such large returnee communities on the environment in general and the pastoral lands in particular will be significant given the deteriorating environmental conditions in the country. The most serious environmental impacts that are likely to occur are as a result of agricultural activities, demand for fuelwood, and to a certain extent, construction. In the western lowlands it is expected that some 50,000 ha of farm land will be allocated to returnees. Thus the pastoralists are being deprived of some grazing land, creating pressure for livestock production. In addition, clearing the vegetation on these lands will expose the soil to erosion and loss of fertility. The amount of wood required for fuel and construction will also be very high.

These resettlements could also have some beneficial impact on their surroundings. The production of food and cash crops could contribute to self-sufficiency. The basic services that would be provided to the resettlement sites, such as health, water, education, grinding mills and access roads, will have a positive effect on the surrounding communities. In addition, the surrounding communities would have easy access to markets.
The case of Sawa area

Sawa can be taken as an example of an area where there is a potential for conflict over resource use. This area is endowed with good soils and riverine vegetation, and it is this resource that has become the source of disagreement. The competing parties are the local pastoralists on the one hand and horticulturalists on the other.

A discussion with these two parties was conducted in May 1995. It was found that this riverine area was traditionally a grazing resource for the livestock of the area, mainly goats. Horticultural activities were started with the permission of the administration and Baito (local assembly) officials in 1992, mainly by returnees from the Sudan and some local people with financial resources. Since then, horticulture has expanded so rapidly that vast riverine areas have been cleared for this purpose.

The pastoral people said that they had no objection to agriculture in general, but they object to these horticultural activities near the river because:
- Riverine vegetation is being destroyed. Destruction of these resources could mean the destruction of their livestock and, therefore, of their livelihood.
- Since the horticultural gardens are between the villages and the riverbed, they block access to the water source.
- Livestock were being detained, injured and sometimes killed by the horticulturalists when they happened to stray into their gardens.
- The horticultural activities are constantly expanding and causing much resource destruction. In conclusion, they recommended that such farming should take place away from the riverine areas.

For their part, the horticulturalists said that:
- The pastoralists deliberately allow their livestock to stray into their gardens.
- Livestock should be herded away from the horticultural gardens.
- Regulations should be established by the authorities providing for fines to be imposed on livestock owners who allow their animals to stray into the gardens.

11.8 Conclusion

There is some tension between the competing parties, i.e. the pastoralists and the farmers/horticulturalists. If this situation is left to continue, the potential conflict could escalate.

11.9 Recommendation

An attempt should be made to identify and remove the negative environmental effects deriving from such development activities.

**SKILLS REQUIRED**
- Knowledge about pastoralist production systems.
- Knowledge about the requirements of farmers and horticulturalists in the area.
- The ability to mediate in conflicts between farmers and pastoralists.
BIBLIOGRAPHY


APPENDICES

Appendix I

‘Skills required by an extension worker’: summary of case studies

This summarized list of ‘skills required’ has been sorted into three groups based on the authors’ assessment of their relative importance for practical implementation of soil-conservation measures in Eritrea and inclusion in a possible future manual on the subject. The first group includes the points considered relevant; the second, points that may be of marginal importance; and the third points that were felt to be less relevant.

1. To include in a manual on soil and water conservation
   - Layout of contours.
   - Terrace construction.
   - Ability to make decisions about spacing between terraces using a vertical interval that is decided according to soils, vegetation and slope.
   - Construction of checkdams.
   - Layout of contours, construction of terraces and other structures, both on cultivated land and on hillsides.
   - Cost-effective designs on hillsides (a few terraces or none, micro-basins).
   - Ability to determine areas that should be closed.
   - Understanding the importance and management of ghedena.
   - Knowledge of biological soil conservation measures.
   - Knowledge of the use of manure, crop residues and fertilizers and other methods for soil fertility maintenance.
   - Knowledge of techniques for gully protection and diversion ditches.
   - Knowledge of suitable species for planting along river banks, including propagation techniques.
   - Knowledge of gabion construction techniques.
   - Knowledge of methods for river-bank protection in lowland areas with flash floods in seasonal rivers.
   - Knowledge of physical and biological soil conservation measures and how they can complement each other.

2. For possible inclusion
   - The ability to design and implement a forest management system that secures benefits to the communities.
   - Understanding the importance of topsoil versus subsoil and applying that knowledge practically.
   - Knowledge of the ecological requirements of the most common tree species.
   - The ability to secure the full participation of communities in management and protection of vegetation.
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- Methods for securing the participation of local communities.
- Extension methods.
- The ability to interact and communicate effectively with local people.
- Knowledge of a wider range of tree species, e.g. for fruit and fodder.
- Ability to identify areas on hillsides where tree planting is not worthwhile, e.g. where the soil is too shallow.
- Knowledge of tree-seedling quality and post-planting care.
- Knowledge of intercropping: suitable crop combinations, etc.
- Knowledge of afforestation.
- Training skills.
- Knowledge of roof-water harvesting.
- Knowledge of different tree and shrub species for different environments.
- Knowledge of the cut-and-carry system, especially to determine when it is feasible and when not, e.g. with regard to distance.
- Knowledge of the use of mulch for tree seedlings.
- Knowledge of agroforestry technologies (including development of homegardens) and their potential and constraints.
- Knowledge of relevant land laws and possible resulting constraints.
- Knowledge of construction of above- and below-ground water tanks.
- The ability to facilitate formation of water-user committees.
- Design of small-scale irrigation systems.
- The ability to analyse the socio-economic consequences of interventions such as area closures and dams.
- The ability to act as a mediator in situations of conflict between different groups.
- The ability to assess livestock carrying capacity in different areas and in relation to planning area closures.
- Knowledge of the importance of riverine vegetation.
- Knowledge of rules and regulations regarding cultivation along rivers.
- Knowledge of species of grasses and trees suitable for roadside planting.
- Knowledge of road design and requirements (road engineers) to be combined with the ability to assess erosion on different types of land (agriculturalists).
- Knowledge of larger scale irrigation techniques, including construction and maintenance of water-diversion structures, irrigation canals, embankments, etc.
- Knowledge of dam construction and management.
- Knowledge of all the techniques involved in the spate-irrigation system.
- Knowledge of pastoralist production systems.
- Knowledge of the requirements of farmers and horticulturalists when there is a conflict of interests between them.
- Ability to mediate in conflicts between farmers and pastoralists.

3. Not to be included
- Forest-fire prevention.
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- Knowledge of non-wood forest products, e.g. bee-keeping.
- General agricultural knowledge: seeds, cultural practices.
- Knowledge of methods of termite control.
- Knowledge of a variety of fruit trees, their requirements, propagation, etc.
- Knowledge of small-scale poultry development.
- Knowledge of vegetable seedling production and vegetable production generally.
- The ability to give advice on credit and formation of marketing co-operatives.
- The ability to assist farmers in establishing marketing co-operatives.
Appendix II

Summary report of the workshop

Participants
Belay Habtegabr  Head Office, Ministry of Agriculture, Asmara
Kibrom Beyene  Head Office, Ministry of Agriculture, Asmara
Eyob Zemical  Head Office, Ministry of Agriculture, Asmara
Isaac Kafil  Gash Barka Zone (Barentu)
Senait Tekle  Debub Zone (Halhale)
Bahta Tedros  Anseba Zone (Keren)
Mogos Woldehannes  Head Office, Ministry of Agriculture, Asmara
Mahamed Salih  Head Office, Ministry of Agriculture, Asmara
Thomas Beyene  Makel Zone (Serejeka)
Ghebremical Fesahazon  Debub Zone (Dibarwa)
Fekadu Tesfamariam  Gash Barka Zone (Forto)
Semere Zaid  Asmara University
Iyob Zeremariam  Head Office, Ministry of Agriculture, Asmara
Teklu Kidane  Semenauli Keih Bahri Zone (Sheeb)
Astar Weldezghi  Makel Zone (Tsodkristian)
Teklehaimanot Zerai  Anseba Zone (Halhal)
Yohannes Habte  Debub Zone (Mendefera)
Ibrahim Salh  Anseba Zone (Keren)
Mebrahtu Iyassu  Head Office, Ministry of Agriculture, Asmara
Bo Tengnäs  RELMA (Nairobi)
Amanuel Negassi  Head Office, Ministry of Agriculture, Asmara
Hagos Yohannes  Head Office, Ministry of Agriculture, Asmara

1. Welcoming address by Mr Mebrahtu Iyassu, Head of Land Resource and Crop Development Department, Ministry of Agriculture.
2. Presentation of the workshop participants.
3. Mr Amanuel Negassi explained that the purpose of the workshop was to review and discuss findings from a number of case studies on soil conservation in different agro-ecological settings in Eritrea, and to give advice to the team proposing to prepare a manual on soil and water conservation on the desirable contents of such a manual.
4. Mr Negassi presented the case studies and invited the participants to comment on the findings and conclusions. The discussion was extensive and relevant points were to be incorporated in the case reports before they are published.
5. The participants were divided into three groups and asked to study the summarized ‘skills required’ (Appendix I), and to change the classification of them such that only two groups would remain, i.e. what to include and what not to include in the manual.
6. Findings from the groups: the three groups reported that more or less all the points were relevant. One group suggested that ‘knowledge of the land law and possible resulting constraints’ would not be a priority, another group that ‘ability to act as a mediator in situations of conflict between different groups’ would not be the work of an extension officer and thus not relevant for discussion in a manual. Yet another group felt that protection against forest fires was not a prime concern, and another that poultry development may not be a priority for the manual.

Some new points were added, and after deleting those regarded as doubtful, the list of points suggested for inclusion in a manual was as follows:

- Layout of contours.
- Terrace construction.
- Decision-making ability on spacing between terraces using a vertical interval that is decided according to soils, vegetation and degree of slope.
- Construction of checkdams.
- Layout of contours, construction of terraces and other structures, both on cultivated land and on hillsides.
- Cost-effective designs on hillsides (few terraces or none, micro-basins).
- Ability to determine areas that should be closed.
- Understanding the importance and management of ghedena.
- Knowledge of biological soil conservation measures.
- Knowledge of use of manure, crop residues and fertilizers and other methods for soil fertility maintenance.
- Knowledge of techniques for gully protection and diversion ditches.
- Knowledge of suitable species for planting along river banks, including propagation techniques.
- Knowledge of techniques of gabion construction.
- Knowledge of methods of river-bank protection in lowland areas with flash floods in seasonal rivers.
- Knowledge of physical and biological soil conservation measures and how they can complement each other.
- The ability to design and implement a forest management system that secures benefits to the communities.
- Understanding the importance of topsoil versus subsoil and applying that knowledge practically.
- Knowing the ecological requirements of the most common tree species.
- The ability to secure the full participation of communities in management and protection of vegetation.
- Methods for securing the participation of the local people.
- Extension methods.
- The ability to interact and communicate effectively with local people.
- Knowledge of a wider range of tree species, e.g. for fruit and fodder.
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- The ability to identify areas on hillsides where tree planting is not worthwhile, e.g. where soil is too shallow.
- Knowledge of tree-seedling quality and post-planting care.
- Knowledge of intercropping: suitable crop combinations, etc.
- Knowledge of afforestation.
- Training and demonstration skills.
- Knowledge of roof-water harvesting.
- Knowledge of different tree and shrub species for different environments.
- Knowledge of the cut-and-carry system, especially to determine when it is feasible and when not, e.g. with regard to distance.
- Knowledge of the use of mulch on tree seedlings.
- Knowledge of agroforestry technologies (including homegarden development) and their potential and constraints.
- Knowledge of construction of above- and below-ground water tanks.
- The ability to facilitate formation of water-users committees.
- Design of small-scale irrigation systems.
- The ability to analyse the socio-economic consequences of interventions such as area closures and dams.
- The ability to assess livestock carrying capacity in different areas and in relation to planning area closures.
- Knowledge of the importance of riverine vegetation.
- Knowledge of the rules and regulations regarding cultivation along rivers.
- Knowledge of the species of grasses and trees suitable for roadside planting.
- Knowledge of road design and requirements (road engineers) to be combined with the ability to assess erosion risk on different types of land (agriculturalists).
- Knowledge of larger-scale irrigation techniques, including construction and maintenance of water-diversion structures, irrigation canals, embankments, etc.
- Knowledge of dam construction and management.
- Knowledge of all the techniques involved in the spate-irrigation system.
- Knowledge of pastoralist production systems.
- Knowledge of the requirements of farmers and horticulturalists when there is a conflict of interests between them.
- The ability to mediate in conflicts between farmers and pastoralists.
- Knowledge of non-wood forest products, e.g. bee-keeping.
- General agricultural knowledge: seeds, cultural practices.
- Knowledge of methods for termite control.
- Knowledge of a variety of fruit trees, their requirements, propagation, etc.
- Knowledge of vegetable seedling production and on vegetable production generally.
- The ability to give advice on credit and on marketing co-operatives.
- The ability to assist farmers in establishing marketing co-operatives.
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- Management of underground water resources, techniques with wells, etc.
- Elementary knowledge of machinery that can be used, e.g. tractors.
- Simple surveying techniques, e.g. use of a line level.
- Use of mulch and other measures for stabilizing soil.
- Controlled grazing.
- Duration and management of closures.
- Grass seeding in closures.
- Drainage problems, especially noting that terraces must be drained to avoid waterlogging.

Other points mentioned were:
- A manual for extension workers can be quite elaborate, whereas materials for farmers must be short and easy to read.
- A manual should be enlivened with illustrations and examples from Eritrea.
- There is a need for pamphlets and posters to popularize various topics.

7. Bo Tengnäs summarized the points into eight broad subject areas and asked each participant to select the three subject areas he felt to be most important. The prioritized list of subject areas was as follows, with the figure indicating the number of participants mentioning the respective subject:

- Physical and biological soil conservation 18
- Irrigation technology 16
- Dam construction/maintenance 6
- Agroforestry 6
- Extension, communication skills 6
- Soil fertility 2
- Rangeland-related issues 2
- Horticulture 1

8. Mr Tengnäs then listed eight agro-ecological settings and asked the participants to prioritize again giving three settings each. The prioritized list of settings was as follows:

- Catchment areas for dams 16
- Rainfed cultivated land 14
- Small-scale irrigation 10
- Hillsides 8
- Spate irrigation 6
- Pastoral areas 2
- Roadsides 1
- Ghedena –

9. Mr Negassi thanked the participants and closed the workshop.
The Swedish Development Cooperation Agency (Sida) has supported rural development programmes 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.

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:
In spite of massive investment in farmers’ labour, tree seedlings and public funds, soil erosion is still a serious problem in Eritrea, especially on sloping crop lands. Because of this, soil fertility and agricultural productivity have declined.

In 1998, a survey was made of various sites selected as being representative of the different land-use systems in the country. Information was gathered in interviews with farmers, extension agents and administrative officers, as well as by observation. Then, the findings of these various case studies were reviewed and discussed at a workshop held in Asmara in October 1998. The discussions focused on selecting the most important subject areas to be covered in a proposed manual for soil and water conservation. Summaries of the case studies and the results of that workshop are presented in this report.

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