Land Management in the Central Highlands of Eritrea

A Participatory Appraisal of Conservation Measures and Soils in Afdeyu and its Vicinity

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Mats Gurtner, Yonas Hadgu, Chris Hergarten

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National Agricultural Research Institute (NARI)
Ministry of Agriculture
P.O. Box 4627
Asmara, Eritrea

Association of Eritreans in Agricultural Sciences
Asmara, Eritrea

Sustainable Land Management Programme (SLM Eritrea)
Centre for Development and Environment (CDE)
University of Bern
Steigerhubelstrasse 3
CH – 3008 Bern, Switzerland
www.cde.unibe.ch
info@cde.unibe.ch

Syngenta Foundation for Sustainable Agriculture
WRO 1002.11.52
4002 Basle, Switzerland
www.syngentafoundation.ch

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Foreword

In a country with erratic rainfall, steep slopes, and low vegetation cover, soil erosion is without doubt a real problem that reduces the productive capacity of the land. The Ministry of Agriculture (MoA) has realised this and is actively engaged in soil and water conservation (SWC) to remediate the effects of soil and nutrient loss.

To-date, most large-scale SWC activities have been based on MoA-initiated campaigns that are dominated by physical structures. The main problem has not been the lack of technologies for soil and water conservation, but the failure to 'motivate' and 'engage' farmers to actively embrace enhanced soil conservation measures. A different more farmer-centred approach is needed. Plenty of scope remains for a more participatory method of developing technically, socially and financially appropriate SWC and watershed management techniques.

This study, therefore, attempts to holistically address the rationale for farmers' acceptance and adoption of appropriate SWC approaches, both indigenous and introduced. The information generated allows for a better understanding of how to integrate local knowledge into future SWC implementation processes, and is practically relevant to the Ministry of Agriculture extension, as well as for specialists working in research and academia.

The efforts of the research team need to be recognised in what has been a lengthy process of participatory research and validation aimed to ensure that the results are as true a reflection of the situation in Afdeyu and its surroundings. In addition, I would like to gratefully acknowledge the Syngenta Foundation for Sustainable Agriculture for their financial support, as well as the Sustainable Land Management Programme, the Centre for Development and Environment of the University of Berne for their expertise and professional support to this study.

It is my deepest conviction that this study will contribute positively towards efforts in reducing land degradation and improving sustainable land productivity in Eritrea.

Dr Iyassu Ghebretatios
Director General
National Agricultural Research Institute
Ministry of Agriculture
The State of Eritrea
2006

Preface

This study deals with soil and water conservation and soils in the Central Highlands of Eritrea. These are key topics relating to development in rural Eritrea in general, and they are high on the political agenda of the government. The Syngenta Foundation for Sustainable Agriculture has taken up this priority in its Eritrea SLM programme as a major component in technical cooperation.

Soil and water conservation is by no means an innovative theme in Eritrea. Yet the study contains several innovative elements. First of all, it is participatory, meaning in this case that it involves researchers and technicians, as well as land users. The back-to-village report and the discussion of the results have shown that there is a great and still largely untapped potential in this approach. Secondly, soil and water conservation is presented and discussed within the framework of rural livelihoods and local farming practices, rather than being dealt with in an isolated way. Thirdly, measures are documented in their spatial arrangements as well as in their technical format.

The wealth of technologies and approaches found is astonishing and presents a complex pattern which is not easy to handle for those who document it. Relating to overall appraisal and documentation of soil and water conservation activities and measures, the present study is partially based on WOCAT methods and tools. WOCAT (World Overview of Conservation Approaches and Technologies) is a global programme with the aim of supporting decision making and innovation in soil and water conservation by connecting stakeholders, enhancing capacity, and developing and applying standardised tools for documenting, monitoring, evaluating, sharing and using knowledge.

The study shows that farmers are experts of their environment – see the example of their soil classification system. The study also shows that they are well aware of the problem of soil erosion and that preventive measures, both local and introduced, are known to them. On the other hand, their resources are extremely limited, especially with regard to resources as crucial as land and labour. Programmes dealing with soil and water conservation and land management in general must be aware of these limitations if their outcomes are to be lasting.

The results of this study are timely. They will serve as a reference for the activities that are planned in soil and water conservation and land management by the partners involved in this study. The study will also be a useful reference for ministry staff, including extension, and for all those involved in teaching and research at institutions of higher education in Eritrea.

Hans Hurni
Thomas Kohler
Programme Directors
Sustainable Land Management Programme (SLM Eritrea)
2006

Acknowledgements

This report is the result of a joint effort: a close collaboration between the National Agricultural Research Institute (NARI, Ministry of Agriculture), Eritrea, SLM Programme Eritrea, the Centre for Development and Environment (CDE), Switzerland, the WOCAT programme (World Overview of Conservation Approaches and Technologies) and the farmers in the study area. The authors would like to express their gratitude to all who have actively participated in this study and contributed their valuable inputs both during field work and during the compilation of the final products, i.e. this report and the geographical information system.

First of all, we would like to thank the farmers in the study area, who were our local experts and key informants. Their profound knowledge of soil and water conservation (SWC) and soil resources definitely forms the foundation of this study. This knowledge, along with their hospitality and cordiality, their indefatigable will to go ahead and struggle against all odds, and the humour they kept despite of the hard environment they are living in, deeply impressed us. There are too many names to be listed here individually, but they are all indicated in “References”.

Thanks to the commitment of and the good collaboration within the interdisciplinary and international study team, consisting of researchers from NARI, WRD and CDE, it was possible to cover an area three times larger than initially planned. The Eritrean researchers played a central role in the communication between the investigators and the farmers, and assured the quality of compiled local knowledge. Thanks also to Semere Asmelash who contributed to the well-organised field work.

External support and backstopping during the field phase and later on, during the review of the report, was provided by numerous persons from different institutions and with different backgrounds. These contributions were an indispensable pillar of the study. Again, there are too many names to be listed here; the complete list is given in the references section. Special thanks go to Abraham Daniel, Estifanos Bein, Iyob Zeremariam, Dr. Mehreteab Tesfai, Selamawit Tesfai, Semere Amlesom, Teklemariam Berhane and Dr. Thomas Kohler.

All these persons, and many others who remain unnamed, have contributed time, knowledge and labour, bearing in mind a common aim: to document what has already been achieved in SWC in Eritrea, and to elaborate an information base for decision-making, for planning of future research activities, and especially for concrete implementation of SWC.

Eventually, we would like to take this opportunity to thank the Syngenta Foundation for Sustainable Agriculture, Basle, for funding the major part of this study.

Mats Gurtner
Goitom Zewenghel
Henok Eyassu
Tesfaalem Zerai
Yonas Hadgu
Brigitta Stillhardt
Paul Roden

Summary

Soil erosion and decline of productivity in agricultural areas are widespread problems in the central highlands of Eritrea, where population pressure leads to intensification of land use and further degradation of the scarce land resources. Aware of these problems, both the government authorities – through systematically implemented large-scale campaigns – and the farmers – on an individual basis – have taken the initiative to implement soil and water conservation (SWC) measures. Nevertheless, problems of acceptance and maintenance of these measures persist, raising the question of the reasons behind adoption or rejection of the various practices.

This is the entry point of the present study. In a **participatory and transdisciplinary field assessment** led by an international study team and involving the local farmers' expertise, an inventory and maps of the soil and water conservation measures and local soil types were prepared based on the example of Afdeyu and its vicinity in the central highlands. Afdeyu was chosen because it is the location of a research station run by the National Agricultural Research Institute (NARI) in collaboration with the Sustainable Land Management Programme (SLM), with over 20 years of records on soil erosion and the effects of preventive measures.

The **inventory of SWC measures** highlights the diversity of SWC measures applied in the area. A total of 13 local and 10 introduced measures are documented in detail and presented in standardised fact sheets, including potentials and weaknesses, farmers' evaluations, and scientific descriptions. Most of the measures are applied on cropland, and there is a clear focus on structural and agronomic measures, whereas vegetative measures are almost inexistent. While little remains to be improved in terms of area coverage, the study has detected a lack of quality in the existing SWC measures, mainly due to a lack of maintenance. The reasons behind this are manifold, the major ones being the influence of off-farm income-generating activities (decreasing importance of agriculture); lack of incentives; lack of manpower; attitudes (individual perceptions, commitment); insecure land use rights (*diessa* system); and land shortage. In principle, most of these aspects refer to limited financial, human and natural resources.

Sustainable land management in such a fragile and densely populated environment depends to a large extent on intact SWC measures. Proper maintenance of these measures, in turn, depends on their acceptance by the land users and their capacity to maintain them. Increase in production, adaptation to the local natural and socio-economic conditions, and the involvement of local knowledge are three keys to acceptance. Local knowledge has been found to exist abundantly, but tools and platforms to pick it up and integrate it into planning, research and implementation of SWC are still lacking. This leads to the **importance of the approaches** used in SWC. In the study area two relevant approaches were identified: 1) externally promoted, incentive-driven mass campaigns; 2) individual initiatives by local land users. Both approaches proved to have their limitations. What is needed is an integrated approach involving all stakeholders and improving communication, mutual learning processes and collaboration between researchers, extensionists and land users. Proper evaluation and monitoring processes are important in order to assess the impacts of SWC interventions and to learn from mistakes and successes.

The **soil assessment** resulted in a consistent local soil typology, applicable to the whole study area and probably larger parts of the central highlands, as indicated by comparative studies from other areas. The local classification is mainly based on visible and tangible soil properties, and related to the topsoil layer. Despite its limitations, it is perfectly appropriate for rapid and cost-effective assessments. The local typology and fertility assessments also showed a good correlation to those of the FAO classification.

All spatial data collected in this study – both on soils and on SWC – are geo-referenced and integrated into a **geographical information system** (GIS), allowing for the production of maps at different scales on different topics. A selection of 6 maps is presented at the end of this report. Overlaying several maps allows for more detailed analysis of interrelations between different factors.

Fact sheet of the study area

Location:	Villages: Afdeyu, Adi Jin, Quandoba and Tsehaflam; Sub-*zoba*: Serejeka; *Zoba*: Maekel; Central Highland Zone; 25 km northwest of Asmara
Altitudinal range:	2280–2540 m a.s.l.
Climate:	Semi-arid; rainfall: 458 mm*, temperature: 18.4°C* (*annual average)
Agroclimatic classification:	Moist highland zone (locally *kebesa*, or *weyna dega*), potential growing period: 4–5 months per year
Soils:	Predominantly Cambisols; some with luvic properties; partly associated with lithosols (leptosols) on ridges or with fluvisols in valley floors; loamy soils with high gravel content and low nutrient status
Water:	Intermittent streams, dry out shortly after the rainy season; main stream is called Mayketin River
Wood:	No primary forest; area closures with tree plantations (mainly eucalyptus, and acacia)
Population:	Total population (Afdeyu): 1592; total number of households: 413; average household size: 4 persons
Religion:	Predominantly Orthodox Christian; each village has its own church
Education:	Primary schools in Tsehaflam and Quandoba; Secondary school in Serejeka (2 km from Afdeyu)
Health:	Nearest health station at Serejeka (2 km)
Infrastructure:	Electricity in Afdeyu (since 2005); 2 wells (in valley bottom, not in village); all-weather road access; few small shops
Markets:	Serejeka (main market day: Friday); Asmara (25 km, frequent bus connections)
Farming system:	Subsistence-oriented mixed farming: mainly rainfed crop production, very few irrigated areas; livestock; small-scale, traditional ox-drawn ploughing, few farmers hire tractors
Crops:	Main: wheat, barley; secondary: linseed, maize, lentils, beans, finger millet, *teff*, potatoes, onions, some vegetables (on irrigated plots)
Livestock:	Cattle, goats, sheep, donkeys, chicken
Land tenure:	*Diessa* system: individual user rights; land redistribution every 7 years
Main agricultural problems:	Land scarcity, high rainfall variability (droughts), soil erosion, lack of fertiliser and irrigation facilities, decreasing soil fertility, low productivity, and resulting problems of food self-sufficiency

Marginal, communal areas provide no direct benefits to individual land users. As a consequence, damaged soil and water conservation structures are not maintained, which opens a door to degradation processes on the spot and further downstream. Part I of this study highlights the natural and socio-economic framework conditions, the land management practices and the resulting problems in the study area (Photo 1).

Background

Problem statement

Aims and objectives

Geographical setting

Problem statement

Around 80% of all Eritreans derive their livelihood from agriculture and related business. In the Central Highland Zone, the most widespread form of agriculture is small-scale subsistence farming. Population pressure on the scarce resources is high and land degradation has reached an alarming level, considerably reducing productivity and thus posing a direct threat to farmers' livelihoods.

The government of Eritrea and NGOs have made great efforts towards large-scale implementation of soil and water conservation (SWC) measures. Over a period of 13 years (1979–1992) around US$ 116 million were invested in food-for-work campaigns to implement SWC measures throughout the country (World Bank 1994, in Semere Zaid 2002). Several incentive-based SWC projects have been carried out in Afdeyu, the most recent one during 1999/2000, when hundreds of kilometres of contour bunds combined with tied ridges were introduced in the catchment with the main aim of protecting existing and planned dams downstream from siltation. The introduced measures were found to control runoff efficiently – by storing 50% of the former discharge within the catchment – and considerably lowering the sediment yield (Burtscher 2002). Some of these structures have been maintained and even replicated, while others have been abandoned once the project ended; in certain areas, the process of decay began soon after implementation.

Also, during the past 20 years, tests were conducted at Afdeyu research station on the effects of different structural SWC measures along the contour on soil loss and runoff. From a technical point of view, the most effective measures with regard to soil loss reduction, runoff reduction and water harvesting were level *fanya juu* and level double ditches (Stillhardt et al 2002). Despite the positive research results neither of these two measures has ever been implemented on farmers' fields.

These developments raise the question about the reasons for adoption or rejection of SWC measures by farmers. What are the motives that make farmers maintain measures, abandon them, or even intentionally remove them?

Why an inventory of SWC measures?

Documentation of SWC measures

Diversity of SWC measures: Earlier reports and research papers (Virginia Dawod et al 1999, Abraham Tsegai et al 2001, Semere Zaid 2002) have mentioned only a very limited range of SWC measures applied in the research area, i.e. stone and earth bunds, partly in combination with tied ridges, on agricultural fields, and check dams and micro-basins in reforestation areas. The actual diversity of SWC measures applied in the study area, however, is expected to be much higher. Furthermore, a documentation of SWC measures should go beyond the description of technical details and emphasise land users' perceptions, including an analysis of benefits, problems and acceptance based on farmers' perceptions.

Focus on both introduced and local measures: SWC practices that have been applied over generations tend to be well-adapted to the natural and socio-economic environment. Therefore, they usually enjoy a high level of acceptance, which is a key prerequisite for persistent and proper maintenance of SWC measures and thus for effective conservation and sustainable land management. So far, however, studies on SWC in Eritrea have placed little to no emphasis on local conservation measures. Thus, knowledge of local measures and their potentials and limitations is still insufficient, and available knowledge has not been systematised. Integration of local practices in external approaches requires detailed study of indigenous components. (Krüger et al 1997)

Monitoring and evaluation

Previous evaluations of introduced SWC measures focussed on quantitative reporting of physical targets (e.g. length / number of implemented conservation measures) or financial indicators. To date, no monitoring activities have been carried out to assess the quality (status) and impact (effectiveness) of SWC measures on farmland, either in general or specifically for the technologies that were implemented during large-scale MoA-directed SWC campaigns in 99/00.

Farmers' perceptions have never been systematically included in monitoring activities. Therefore, there is a need 1) to assess both the (technical) effectiveness and the acceptance (among farmers) of implemented SWC measures, and 2) to identify limitations as farmers perceive them. Feedback from land users is essential for a better understanding of success and failure, as well as for future planning with a view to improving approaches and finding measures that are adapted to local conditions and accepted by the local community of land users.

Why a soil inventory?

Need for geo-referenced soil data

The Afdeyu research station has been providing data on runoff, soil erosion and various climatic parameters for over 20 years. Existing information on soils is superficial, partly contradictory or incomplete, and therefore in need of revision. To date, no soil survey has been carried out to complement the existing database with detailed information on soil characteristics. Available spatial information is very general, as provided in the General Soil Map of Eritrea (FAO 1994) and the soil texture map of Mayketin River catchment (Michael Kidane Mebrahtu 1997). A detailed and comprehensive map containing information on field level will be of great value for further research activities in the area. Soil samples taken so far are not geo-referenced. Geo-referencing is a precondition for a spatially exact monitoring of changes.

Local classification

Local soil classifications have proved to be valid and objective in many cases and in different regions of the world (Ettema 1994). They can offer important insights into local criteria and perceptions of soils in relation to agricultural production. However, local soil classifications cannot provide in-depth analysis of soil parameters from a scientific point of view. A good correlation between local classifications and that made by the FAO can facilitate better communication with local stakeholders and serve as a basis for rapid assessment of soil properties, which are characterised by spatial and temporal variability.

Research activities – so far and in future

The Afdeyu research station was established in 1984, as part of the Soil Conservation Research Programme (SCRP). SCRP built up and managed a total of seven research stations in different agro-climatic belts of the East African highlands that continue to provide long-term monitoring data on river discharge, soil erosion processes, and the effect of different soil conservation measures on soil loss and runoff. Afdeyu is the only station located within today's boundaries of independent Eritrea and is thus of great importance for national research activities in the field of sustainable land management.

Currently the station is in a stage of transition. Several infrastructural upgrades (renovation of buildings, new river gauge station, improvement of climatic measurements) have recently taken place, and the staff has been expanded. New fields of research will be involved, such as research on highland crops and their improvement, as well as tissue culture (field trials).

Given these changes, there is a need for evaluation and monitoring of all activities. The results will provide sound data as a basis for formulating improved soil and water conservation concepts, as well as specific research questions.

In November 2001, during the "Workshop on Long Term Monitoring in Afdeyu" in Asmara, the representatives from the MoA, UoA, CDE and other institutions compiled a list of lessons learnt, research needs (visions) and recommendations, which included among others:

- the need for detailed studies / inventory of local SWC practices; assessment of farmers perceptions
- the need for a systematic soil survey
- the need to formulate research questions based on discussions with farmers

Aims and objectives

Overall goals

1. Assessment of soil and water conservation measures and soil types (local and scientific) providing information as a basis for
   - participatory formulation of research questions and further research activities
   - making decisions regarding the implementation of locally adapted and accepted SWC measures
   - monitoring the performance and effects of SWC measures
2. Testing of an appropriate methodology for rapid participatory assessment of land use problems, SWC options, and soil types for the central highlands of Eritrea based on farmers' perceptions and knowledge.

Specific objectives

Objectives of the SWC assessment

1) Documentation of the diversity of both introduced and local SWC measures:
   - Description of each SWC measure, its purpose, benefits and problems
   - Generating maps to show the spatial distribution of SWC measures and their condition

2) Monitoring of both introduced and local SWC measures:
   - Assessment of their quality (condition / level of maintenance), area cover (extent) and efficiency
   - Assessment of their acceptance / adoption by farmers: limitations regarding establishment and maintenance (→ reasons for success and failure)
   - Identification of promising measures and approaches, adapted to local conditions and needs

3) Lessons learnt:
   - For SWC research (Afdeyu station programme and general)
   - For practical implementation of SWC measures in the future

Objectives of the soil survey

1) Develop a soil typology based on local classification:
   - Definition and detailed description of local soil types (soil characteristics)
   - Generating maps of local soil types and their fertility status to show their spatial distribution

2) Compare local soil classification with the FAO classification and find possible correlation

Other objectives

1) Land management:
   - Assess constraints on agricultural production and on SWC activities
   - Identify local needs

2) Geographical information system (GIS):
   - Set up a geographical information system containing maps / layers on SWC measures, land use, soil types and degradation to show their spatial distribution and interrelations

3) Information management / communication plan:

- Communicate study results to farmers, extensionists and researchers
- Provide a platform to develop integrated participatory approaches
- Set up an information pool for Afdeyu: collect studies and other data regarding the Afdeyu area and SWC in general and make it available to interested persons
- Contribute to a common basis for communication between scientists and local stakeholders

4) Methodology:

- Focus on farmers' perceptions and needs and on participatory methods
- Contribution to the development of an appropriate method for rapid participatory assessment of soil types and their properties in the central highlands of Eritrea

Target group / readership

The target group of the report in hand and the geographical information system includes:

- Soil conservation experts, planners and decision-makers at the regional / national level
- Agricultural extensionists and development agents at the local or community level
- Researchers working in the field of soil and water conservation
- Teachers, trainers

The fact sheets of the identified SWC measures and the outcome of the workshop discussions will be translated into the local language (Tigrinya) in order to make the results accessible to the community, as well as to the non-English-speaking extension staff at the Sub-*zoba* level.

Photo 2: *Local key informants and external researchers bend over a satellite image, which was used as basis for mapping. The study was strongly based on local knowledge and participatory assessment methods.*

Geographical setting

The present study took place in Afdeyu and its vicinity in 2004. Research activities in this area started 20 years ago and included long-term measurements on various climatic factors, runoff and river discharge, erosion and effectiveness of SWC measures, as well as land use mapping. Numerous supplementary studies were carried out by BSc, MSc and PhD students, as well as by consultants and experts. (Stillhardt et al, 2002). The following sections present a comprehensive overview of updated information on the natural and socio-economic environment of Afdeyu area – or in other words the framework conditions the land users are confronted with.

Location of the study area

The study area covers 562 ha and is located about 25 km northwest of Asmara, in the Central Highland Zone[1] of Eritrea, within Maekel *Zoba* and Serejeka Sub-*zoba* (between latitudes of 15° 29' 25"–15° 31'10" and longitudes of 38° 50' 48" – 38° 52'25"). It comprises the catchment of the seasonal Mayketin River (177 ha) plus the territory of Afdeyu village outside the catchment (415 ha). In administrative terms, the catchment is shared by three villages: Afdeyu, covering the largest part in the southwest; Adi Jin and Quandoba in the north. The villages are located along the new tarmac road connecting Serejeka and the eastern lowlands.

Natural environment

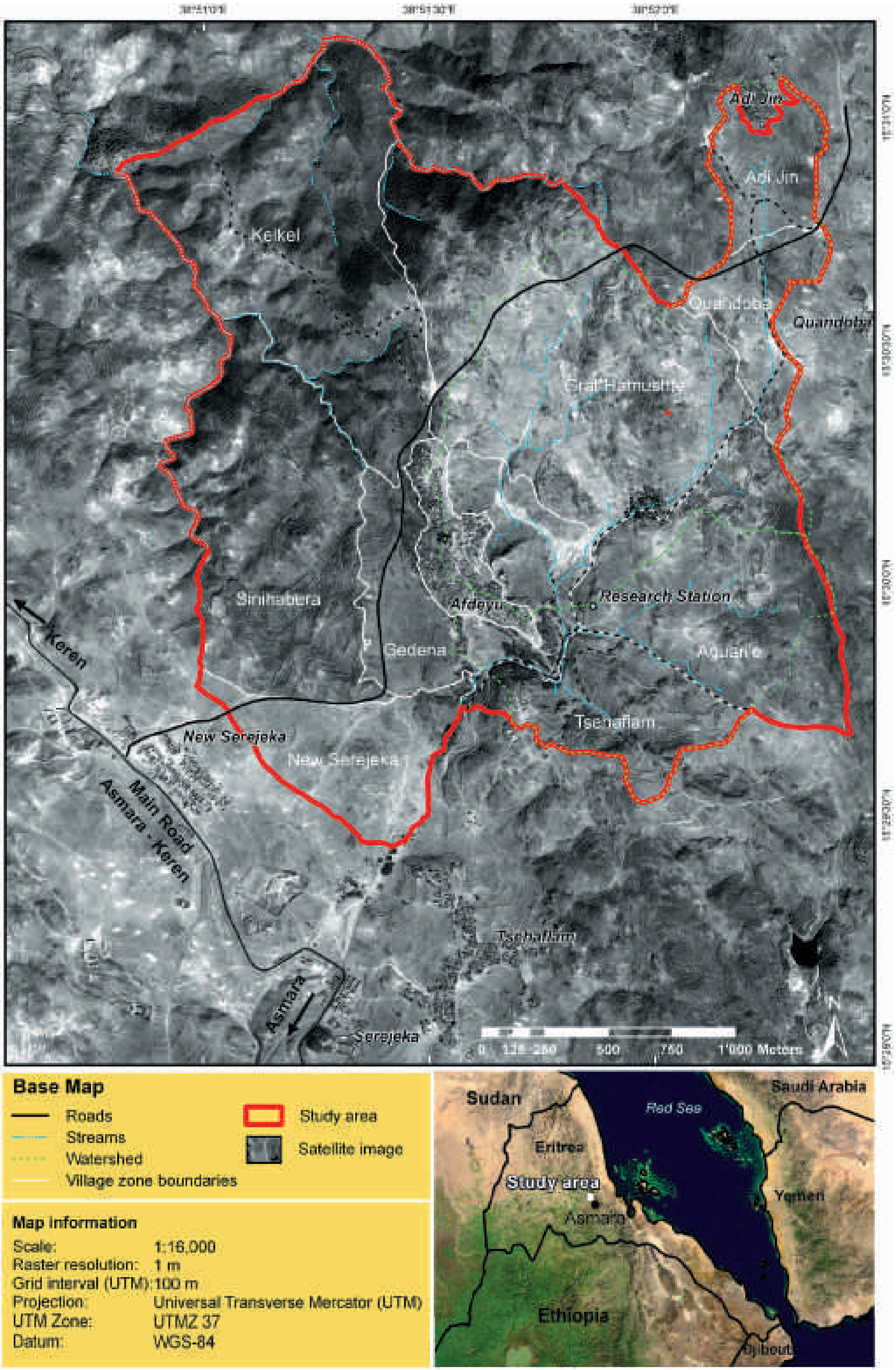
Geology and topography

The study area is situated at altitudes ranging from 2280 to 2540 m a.s.l. The catchment area consists predominantly of gently rounded hills interspersed with relatively flat-bottomed valleys. The territory of Afdeyu situated northwest of the Mayketin catchment consists of deeply intersected hilly to mountainous terrain with steep slopes.

The bedrocks in the study area belong to the Precambrian basement of Eritrea. They consist of schists that developed from intermediate to felsic volcanics through metamorphosis. The extent of schistose foliation varies throughout the area. Where foliation is highly developed, it shows a steep dip angle. In other, less strongly foliated outcrops, columnar jointing is still quite clearly visible. The numerous quartz veins found throughout the area may be the evidence of a high silica content in the bedrocks, which date from the Neoproterozoic and are around 810 million years old. Around 30 million years ago, the bedrocks underwent a process of laterisation. Laterite is a residual deposit of mainly iron and aluminium hydroxides formed by the intense weathering of rocks in humid, tropical conditions. Laterisation produced a very light-coloured, fine-grained and clay-rich rock which now outcrops in some parts of the area as a soft crumbly rock grading upwards into the soil with no clear boundary between the two (see "White soil," page 127) (Virginia Dawod et al 1999).

Map 1 *(page 21): Location of the study area*
Sources: Sattelite image: GEOEYE 2000 (IKONOS II); other features: SLM Database 2004

[1] Zone between 1500-2400 m asl, mean annual temperature 17.5 C°, mean annual rainfall 500–700mm (according to UNCCD NAP)


Adi Jin
Adi Jin
Kelkel
Quandoba
Quandoba
Grat Hamushte
Research Station
Afdeyu
Sinihabera
Gedena
Aquarie
Tsehaflam
New Serejeka
New Serejeka
Keren
Main Road
Asmara - Keren
Tsehaflam
Asmara
Serejeka
0 125 250 500 750 1'000 Meters
Base Map
Roads
Streams
Watershed
Village zone boundaries
Study area
Satellite image
Map Information
Scale: 1:16,000
Raster resolution: 1 m
Grid interval (UTM): 100 m
Projection: Universal Transverse Mercator (UTM)
UTM Zone: UTMZ 37
Datum: WGS-84
Sudan
Saudi Arabia
Red Sea
Eritrea
Study area
Asmara
Yemen
Ethiopia
Djibouti

Climate

The climate in the study area is semi-arid. As in most parts of Eritrea, the rainfall pattern is sporadic and rainfall variability is high, both temporally and spatially. The rainfall regime is bimodal, with the main rainy season (summer or *kremti* rains) lasting from the end of June until September, and the more unreliable short rainy season (spring or *akeza* rains) lasting from mid March to late April or May. The short rainy season is characterised by a particularly high rainfall variability, and rainfall is often erratic (Virginia Dawod et al 1999). During a total of 7 months per year (June and November through April), the climatic conditions in the study area are arid. Total annual rainfall varies considerably over the years. High-intensity rainfall events are common and cause heavy runoff, flooding, and soil erosion. Erosive storm events are registered on an average of 6.5 days per year.

Annual rainfall records from Afdeyu research station from 1985 to 1998 show a maximum of 658 mm in 1995 and a minimum of 259 mm in 1989. The mean annual rainfall during this 14-year period is 458 mm (Stillhardt et al 2002). Local farmers attribute the sporadic character of the rainfall pattern to the process of desertification which is gradually affecting the area (TOKER 1996). Streams are intermittent and highly dependent on rainfall.

The mean annual temperature is 18.4 °C. The warmest period lasts from March through May, with average monthly maximum and minimum temperatures of 26.5 °C and 14.1 °C, respectively. The period from November through February is the coldest time of the year, with a mean monthly maximum of 23.8 °C and a mean monthly minimum of 9.2 °C (Semere Zaid 1998, in Virginia Dawod et al 1999).

According to the classification of agroecological zones (Ministry of Land, Water and Environment), the study area lies within the "moist highland zone". (Ghebru K, Randcliffe D 1997) According to the Agro-climatic Classification of Eritrea, the catchment is located in the *kebesa* zone, also known as *weyna dega* (Stillhardt et al, 2002).

The dominant wind direction in the area is from east to west, although westerly winds often occur in the evenings. Mean daily evaporation per month measured with a Pichet evaporimeter ranges from a minimum of 2.3 ml in August to a maximum of 8.5 ml in March (Stillhardt et al 2002).

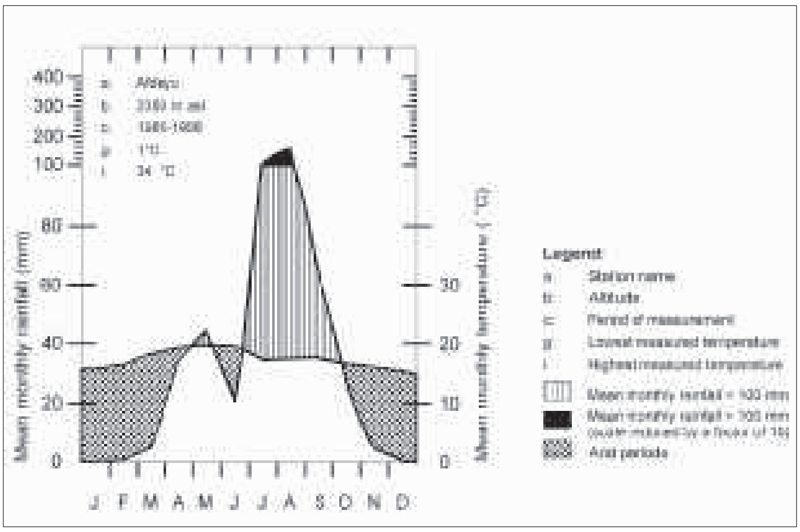


Figure 1: Mean monthly rainfall and mean monthly temperature in Afdeyu. (Source: Afdeyu Station; in Stillhardt et al 2002)

Photo 3: *The first rains of the rainy season hit the bare soil with high intensity, causing high erosion rates and flooding of the fields despite the SWC measures in place.*

Vegetation

Back around 1900, 30% of Eritrea was covered by forests. Particularly the highlands were much more densely forested. However, heavy forest use during the last four to five decades – extraction of wood for the construction of traditional houses and for making agricultural tools, as well as, most importantly, fuelwood extraction and conversion of forest to agricultural land – has led to a dramatic decrease in forested area, with the present forest cover estimated at 1% or less (NEMPE 1995, in Virginia Dawod et al 1999, complemented by Iyob Zeremariam, personal communication 2006). According to local key informants, Afdeyu had a considerable natural forest cover in the pre-colonial era. The Italians then started to cut immense quantities of *Olea africana* for industrial use, as well as acacia for charcoal production (TOKER 1996).

Today, there is no natural forest cover left in the study area, except for two small local reserves in Adi Jin and Quandoba. From 1983 onwards, afforestation programmes started to establish *Eucalyptus* plantations in closed areas. Large parts of the territory of Afdeyu outside the catchment are currently covered with such plantations. Remaining native trees and shrubs are confined to the immediate surroundings of churches and few traditional area enclosures. Existing native plant species are listed under "Permanent area enclosure" (local SWC measures, see page 68) and under soil type indicator plants (see page 128).

Soils

According to the General Soil Map of Eritrea (FAO 1994), the dominant soil type is stony cambisol. On ridges, cambisols are associated with lithosols (now grouped under leptosols); on valley floors, with fluvisols (Bosshart 1997, in Stillhardt et al 2002, adapted).

Local soil classification distinguishes three major soil types occurring in the study area:

- *Duka* soil: brown, relatively deep and fertile soil with a high water retention capacity and a good soil structure; most common soil type in the area
- White soil (*tsa'eda hamed*): bright, whitish- to greyish-coloured soil with a very loose structure, low fertility and a low water retention capacity; highly erodible
- Red soil (*keih hamed*): moderately fertile soil of a characteristic red colour; clayey to sandy texture, often occurs in combination with white gravel

Apart from these three soil types there is a very shallow and rocky soil that often occurs in combination with rocky outcrops. This soil is not suitable for crop production and is therefore not classified as a soil type by the farmers.

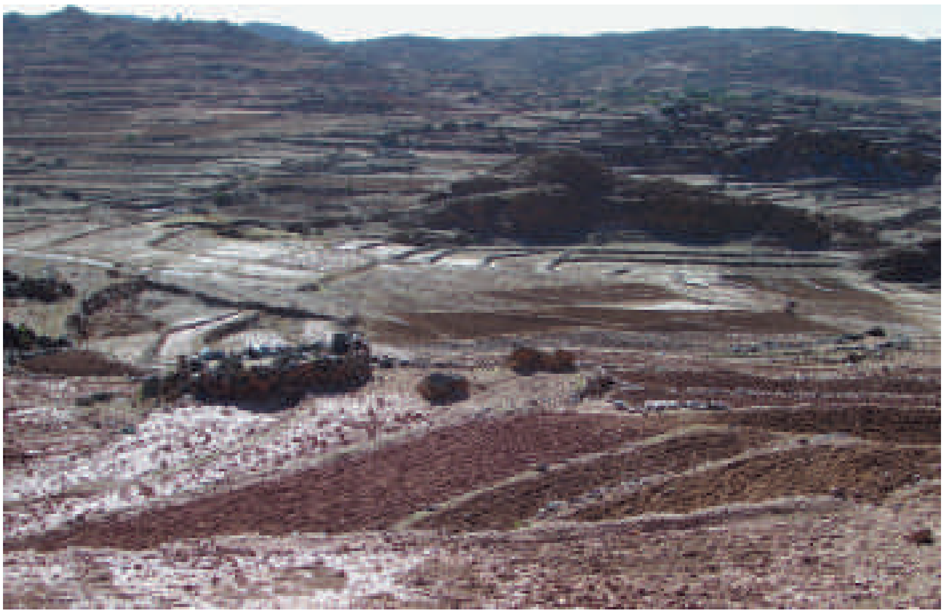


Photo 4: *Situated in the Central Highlands of Eritrea, the study area is characterized by a hilly landscape with fertile soils in the valley bottom and stony, shallow soils on the slopes.*

The volume of gravel in the top layer is generally high (partially more than 50%; Stillhardt et al 2002). While this reduces the area suitable for cultivation, the gravel also protects the topsoil from erosion and increases soil moisture by reducing evaporation. Measured organic matter content and nutrient status indicated that soil fertility is generally rather low. For more detailed information see Part IV, “Chemical soil properties” (page 136).

Socio-economic conditions

Unless otherwise specified, the information provided in this chapter refers to the village of Afdeyu.

Population

More than 30% of the Eritrean population live in the moist highland zone, which makes up 7.4% of the total land area. This area is therefore densely inhabited and intensively used (Ogbaghebriel Berakhi 2001).

Population dynamics in rural areas of Eritrea show clear trends: in only 5 years – between 1998 and 2003 – the population increased by 17%. The latest census data for the study area is given in the tables below. The statistics show a high density of 311 person/km² for Afdeyu. Data on population dynamics at the local level was not available, and is thus given for rural areas in general (see Table 2).

Table 1: *Population data for the three villages in the study area*

Village	Population*	No. of households*	Household size (average)*	Population / km² **
Afdeyu	1592	413	3.9	311
Adi Jin	352	71	5.0	n/a
Quandoba	1228	340	3.6	n/a
Total	3172	824	3.9	n/a

*Source: Statistics Office of Eritrea, 2000 and ** Source: SLM Eritrea 2006

Table 2: Population dynamics: People working in agriculture (national level)

Year	Total population	Annual growth rate (total population)	Population working in the agricultural sector	Annual growth rate (population working in agric.)	Percentage of total population working in the agric. sector
1998	3,464,000		2,708,000		78.2%
1999	3,584,000	+3.5%	2,791,000	+ 3.0%	77.9%
2000	3,712,000	+3.6%	2,879,000	+ 3.1%	77.6%
2001	3,847,000	+3.6%	2,972,000	+ 3.2%	77.3%
2002	3,991,000	+3.7%	3,070,000	+ 3.3%	76.9%
2003	4,141,000	+3.8%	3,173,000	+ 3.4%	76.6%

Source: FAOSTAT data 2006 (figures are estimates)

Economic conditions

Most households in the area live in poverty: in a wealth ranking carried out in 1999 more than 80% of the farmers were ranked as poor or very poor (Stillhardt et al 2002, see Table 3 on page 26).

Although off-farm activities are becoming increasingly important, the majority of the farmers still depend on subsistence agriculture. Yields are not sufficient to cover food requirements throughout the whole year, thus leading to dependence on external food aid.

Farmers are often forced to sell crops at inopportune times when prices are low in order to generate the necessary financial resources to purchase agricultural inputs. Additionally, lack of manpower forces female-headed households, as well as elderly and weak farmers to enter shared investment / shared benefits arrangements (land provided by owner; seed, fertiliser, labour and equipment provided by tenant; each gets 50% of the harvest). Land holdings are very small (see below).

Photo 5: *Traditional houses (hidmo) made of stone, earth and wood as an indicator of the local living conditions: the area is characterised by widespread poverty.*

Most families still live in traditional houses (*hidmo*) made out of stones, earth and wood; only a small number of farmers can afford the construction of new brick houses. The possession of oxen is one of the most important criteria for household wealth ranking. Another important indicator of wealth is the generation of off-farm income by a member of the family who works outside Afdeyu (Stillhardt et al 2002).

Table 3: Wealth ranking Afdeyu 1999

Wealth category	Indicators of wealth	Number of households	Percentage of households
1 (Most wealthy)	2 oxen; 1 or more family members generating off-farm income	11	17%
2 (Moderately poor)	1 ox plus, in some households, 1 donkey; generally no off-farm income	20	30%
3 (Very poor)	No ox; lack of manpower; have to enter shared investment / shared benefits arrangements; depend on external support (relatives)	35	53%

Source : Virginia Dawod et al 1999

Infrastructure and public services

Serejeka, the local centre, is located about 2 km southeast of Afdeyu, on the main road from Asmara to Keren, about 20 km north of Asmara. A new paved road linking Serejeka with the eastern lowlands has considerably improved access to the villages of Afdeyu, Adi Jin and Quandoba. The road passes very close to the villages and offers frequent transport by bus, so that the farmers in the study area no longer depend on rare bus connections and dirt roads which are sometimes impassable during the rainy season. Services provided in Serejeka include a mill, shops, restaurants, telephone, the TOKER project office and the MoA sub-*zoba* office. Market day is Friday.

Afdeyu is connected to the power supply system since 2005, whereas the other two villages are not yet connected. Five small shops in Afdeyu offer the most basic goods, such as tea leaves, coffee, sugar and bread. Two wells with hand pumps are at a walking distance of about 15 to 20 minutes from the village. Only one of them is still fully functional, providing enough drinking water for the whole population. However, a recent laboratory analysis indicates that the water is contaminated with coliform (faecal) bacteria. Water is either transported on donkeys (in water tanks called *jirba*) or carried by women (in jerry cans). The wells are fenced off against animals. It is forbidden to use water from these wells for irrigation purposes. Irrigation water has to be extracted from holes along the riverbed (Stillhardt et al 2002, complemented by primary information).

The nearest primary school is in Tsehaflam, about 1 km from Afdeyu. The capacity of the school building as well as the number of teachers are insufficient. Not every child has the opportunity to attend school. The oldest child of every household is selected first. The drop-out rate during the school year is about 7% for boys and 1.7% for girls. Up to grade 4, the balance between boys and girls attending school is quite even, whereas in grade 5, only 35% of all pupils are girls. In Serejeka there is a junior school and a secondary school (Virginia Dawod et al 1999).

Health services in Afdeyu are very limited. There are two trained midwives who provide childbirth assistance against a small fee. Up to now, most families have refrained from using this service, preferring to have older relatives attend the pregnant women (Stillhardt et al 2002). The nearest health centre, including an ambulance, is in Serejeka.

Local institutions

Several national and local organisations have their representations in Afdeyu (Virginia Dawod et al 1999):

- Village administration: appointed and paid by the government
- Land committee: allocation and periodical redistribution of land
- Development committee: local leader for agricultural issues (contact person for the MoA) and six assistants trained by him, each heading a community group (*com*) in collective activities
- Peoples' Front for Democracy and Justice (PFDJ): representation of political party by 4 leaders, each representing a village section; they have the task of informing the village on government issues
- Farmers' association
- National Union of Eritrean Women (NUEW)
- Youth organisation
- Church organisation

Land tenure

Land holdings

Demographic data show that land use pressure in the area is very high and holdings per household are very small. One household has access to as little as 0.86 ha of land for crop cultivation, of which an average of 60% is of poor fertility. According to the existing land tenure system, cropland is categorised into three levels of fertility (high, moderate and low) and then distributed evenly among households.

Table 4: Land holdings in Afdeyu

Population and land holdings in Afdeyu	
Population size[1]	1592
No. of households[1]	413
Total area of cropland (ha)[2]	355
Population per hectare of cultivated land	4.5
Area of cropland per household (ha[3])	0.86
– high fertility cropland per household (ha)	0.18 ha
– moderate fertility cropland per household (ha)	0.18 ha
– low fertility cropland per household (ha)	0.5 ha

[1] Source: Statistics Office of Eritrea 2000
[2] Source: SLM Eritrea 2006 (includes area reserved for New Serejeka Masterplan)
[3] 1 hectare (ha) = approx. 4 *tsimdi* (local square measure)

Photo 6: Land holdings are small and land shortage is a serious problem in the area: Cropland is fragmented into uncountable plots and periodically re-distributed. Each household gets an equal share.

Village zones

The villages of the study area are traditionally subdivided into zones. The five zones of Afdeyu are: Gedena, Aguari'e, Grat Hamushte, Sinihabera and Kelkel (see Basemap, page 22)

The idea that these categories might be defined on the basis of soil properties or land quality of the respective area, needs to be revised. Subdivision of the village territory primarily serves administrative purposes. The names of the zones relate to different features, such as ancient events or owners, traditional use of the area, topographic features, and others. Subdivision into zones serves two main purposes:

- Crop rotation system and fallowing: each year one zone is under fallow and temporarily closed (for grazing and any other activities)
- Land redistribution: each household owns land in each zone; each zone is classified and divided into high-, medium- and poor-fertility areas.

Gedena is the only zone name that is common to most villages of the Central Highland Zone, and means the land surrounding the residential area of a village. Gedena is the only zone that is permanently cultivated, without intermittent fallow periods.

The land tenure system

In Eritrea there used to be various types of land tenure systems, including:

- *Diessa*: community / village ownership (dominant in the Central Highlands)
- *Risti*: individual ownership (inherited from forefathers)
- *Dominale:* state ownership: individuals pay tax to the government on the land they are using
- *Kahmahse:* traditional land tenure in large farm/grazing areas far away from the village (e.g. in Alla plains)

The new land law adopted in 1994 (Act No. 58) declares that all land now belongs to the state. However, the new law is not yet fully implemented. So far, the old communal tenure system in the study area is maintained, but farmland will not be rotated until the new land law is actually implemented (Amanuel Negassi et al 2000).

Until now, the three villages in the study area still practice the *diessa* land tenure system. Each family is allotted an equal area of land, regardless of the number of persons belonging to a household. Officially, land redistributions are to take place approximately every seven years during a fallow period. However, according to farmers there were only two redistributions over the past 25 years: 1984 and 2000. The date of the next redistribution is not yet defined; farmers are waiting for the government to inform them. Due to its redistribution scheme, the *diessa* system implies insecure user rights and keeps farmers from investing into SWC activities that do not result in direct short-term benefits (local key informants 2004, personal communication).

Land use and problems of agricultural production

Farming system

Crop production

The study area is characterised by small-scale subsistence farming. Land use is mixed, including both crop and livestock production. Cropland is clearly dominant, covering about 70% of the study area.

Agriculture is mostly rainfed. The climatic conditions tend to limit crop growth to the main rainy season (June through September). Around 10 families have set up several small irrigated plots of approximately 50 m² each on the flat alluvial plain near the well in Afdeyu (Stillhardt et al 2002).

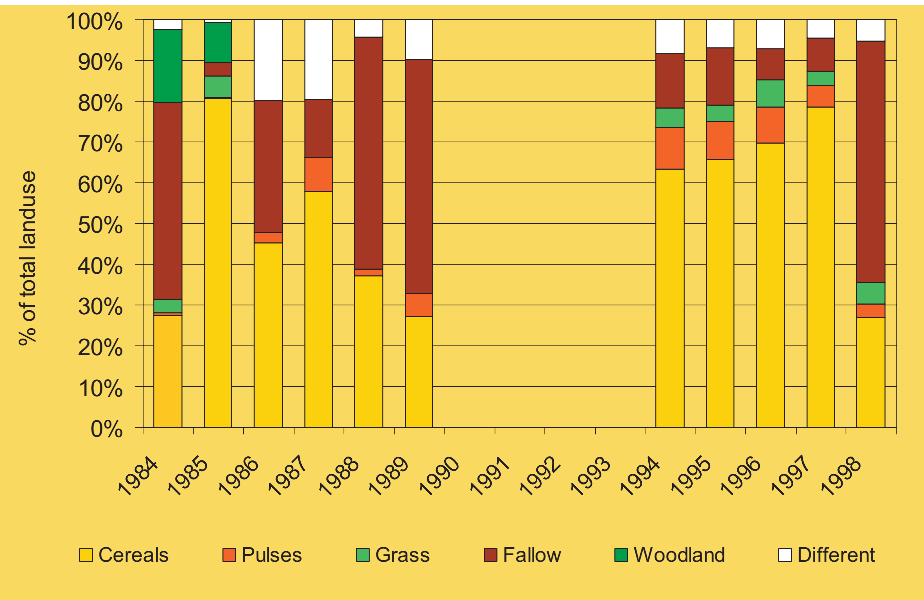


Figure 2: *Land use as percentage of the total cultivated area (1984–1998); Note: The category 'different' includes the irrigated area used for vegetable production and, from 1986 onwards, most probably also woodland; other land use types included in this category are not specified. (Source: Stillhardt et al 2002)*

Traditionally, the main crops in the area are cereals. Wheat and barley cover around 60% of the cropland (Stillhardt et al 2002). Other important crops are linseed, and some pulses (lentils and beans). Some farmers plant maize, *teff*, and finger millet during the small rainy season if conditions are favourable (Semere Zaid 1998, in Virginia Dawod et al 1999).

However, crop failure is common during the small rainy season, the shortage and irregularity of rainfalls being one of the main limitations aside from low soil fertility. Cash crops such as onions and potatoes are grown on fertile, well-managed terraces close to the village, as well as on the few irrigated fields mentioned above. On the latter, crops also include tomatoes.

Crops are grown in rotation, with a fallow period every four years. Consequently, 25% of the total cropland is under fallow each year. A typical cropping cycle consists of wheat in the first year, barley in the second year, and linseed or mixed cropping of barley and wheat in the third year, followed by a year of fallow, during which the parcel is temporally closed also for grazing.

***Table 5**: Calendar of agricultural activities during a 4-year cropping cycle, starting with fallow (applicable for wheat and barley; horse bean, linseed and lentils).*

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Fallow *Tsig'e hamed*	Closure				Grazing (no other activities)				1st plough. (*sito*)	2nd plough. (*aimi*)		3rd plough. (*teslas*)
1st year of cropping *Tsig'e*	SWC maintenance		4th plough. (*mimgab*); SWC maint.	SWC maint.	5th plough. (*mgunbat*); SWC maint.	6th plough. (*mirwah*)	7th plough./ Sowing	(Weeding)		Harvest		
2nd year of cropping *Kerim*	SWC maintenance		ploughing (once; *nekli*); SWC maintenance			optional ploughing (*mirwah*); Sowing (while ploughing)		(Weeding)		Harvest		
3rd year of cropping *Salsien*	SWC maintenance		ploughing (once; *nekli*); SWC maintenance			optional ploughing (*mirwah*); Sowing (while ploughing)		(Weeding)		Harvest		

See "Local ploughing system" (page 73) for explanation of Tigrinya terms used in the calendar

Tillage is done using oxen ploughs and traditional implements. Farmers work through a sequence of different ploughing activities both across and along the contour (see "Local ploughing system," page 73). Recently some farmers have started to plough their fields mechanically using a hired tractor. However, this new practice is not adapted to the local conservation system, which involves a dense network of structural measures. Access to the fields by tractor is difficult and inevitably leads to destruction of stone and earth bunds.

Fertilising in the study area is insufficient. Although the MoA releases chemical fertilisers at a subsidised price, most farmers cannot afford to buy them. The amount of natural fertiliser available is limited, since livestock moves around freely and is temporarily brought to other areas for grazing. Most of the manure is collected, dried and used as an alternative to fuelwood. Pesticides and herbicides are usually applied in low quantities.

The lack of fertiliser, combined with ongoing processes of soil erosion and insufficient recycling of organic matter, is leading to declining soil fertility. Production rates per ha are indicated for different crops in Table 7 (page 35). Low productivity in combination with serious land shortage is causing enormous problems with regard to food security: Productivity is so low that the average annual production feeds a family for no more than four months. Consequently, many households depend on food aid or on family members employed in off-farm activities (TOKER 1996).

***Photo 7**: Field cultivation is carried out using traditional ox-drawn ploughs. This practice is adapted to the small plots and the coverage of structural SWC measures. The level of mechanisation is (still) minimal.*

Livestock

While the main purpose of crop cultivation is the production of food for home consumption, livestock is mainly used for traction and economic security (animals can be sold when funds are urgently needed). Species kept by the farmers include cattle (totally 210 in Afdeyu), oxen (150), donkeys (100), sheep (250), goats (50), and poultry (Virginia Dawod et al 1999). Oxen are used for ploughing, while donkeys are the main means of transportation for goods and services to and from the village. Over 50% of the households do not own any oxen. Animals are entirely endogenous, without improved genetic make-up for growth, meat and milk production, and power for traction. Apart from veterinary services provided by the MoA, no improved methods (e.g. artificial insemination, forage development, introduction of exotic species) are used for livestock production (Virginia Dawod et al 1999).

There is a serious shortage of grazing land in the study area, no more than approximately 10 ha of poor natural pastures are available for 760 animals (large- and smallstock). Uncontrolled open grazing is practised on crop residues (barley / wheat) after harvest (December). Also, immediately after the fallow period, cropland is first opened for grazing before land management activities of the next crop cycle start. Oxen and cows have to be temporarily moved to the eastern escarpment (Bahri, around 13 km away) and to the western lowlands (Virginia Dawod et al 1999). Cut-and-carry of grass in areas closed for afforestation is allowed, but not commonly practised. Farmers are not used to keeping their animals in stalls. Barley and wheat straw is preserved in traditional stone wall circles to serve as fodder in times of shortage (June / July).

Due to fuelwood scarcity, cow dung has become the main source of energy, thus decreasing the availability of manure for application on the fields (TOKER 1996). For a map and additional information on land use types see page 151.

Limitations of agricultural production

Land shortage and growing population pressure (human as well as livestock) have forced farmers to extend cultivation to marginal areas with steep slopes and shallow soils. Land is generally overused, nutrients and organic matter are insufficiently replaced, and loss of topsoil through soil erosion is high. During long periods throughout the year there is no protective vegetation cover, which is particularly problematic at the beginning of the rainy season when the first rains hit the bare soil with high intensity. Measurements on test plots between 1985 and 1990 have shown that on the average, 15% of the annual rainfall events produce about 70% of the total annual soil loss (Stillhardt et al 2002), causing floods with a high sediment load (high erosion rates). Much of the rainwater is lost in the form of surface runoff. Typical soil pillars under grass tussocks (see Photo 8) indicate that much of the fertile topsoil is carried away through sheet or interrill erosion. Mean annual soil loss measured on test plots is 42 tons per hectare, with high variations ranging between 3.1 t/ha and a maximum of 114.3 t/ha. Even with SWC, erosion rates can reach more than 7 t/ha in single years (Herweg and Ludi 1999). As a consequence, crop production per hectare has decreased significantly. Frequent droughts lead to crop failures.

Table 6: Precipitation, runoff and erosion in Afdeyu

Duration of dry season[1]	Mean annual precipitation[1]	Mean annual erosivity[1]	Mean annual runoff[1]	Mean annual soil loss[2]
9 months[3]	382 mm	230 J/m h	162 mm (= 42%)	42.0 t / ha

[1] Period of observation 1985–1990
[2] Period of observation 1988–1990
[3] Mean monthly precipitation < 50 mm
Source: Herweg K and Ludi E 1999

Farmers are aware of land degradation. A range of local and introduced soil and water conservation practices have been implemented. However, maintenance of these measures poses various problems (see PART 2 of this report). Runoff concentrates where conservation structures are not properly maintained or even broken, leading to rill erosion. Over time, rills develop into gullies. Gully erosion has already caused substantial loss of cropping area in the catchment, and gullies cutting through fields hinder land management considerably. Another common phenomenon is pipe (or tunnel) erosion on terraces, which can lead to the collapse of whole terrace sections. Land degradation, in combination with the lack of production-enhancing inputs (fertilisers, irrigation, adequate equipment, seeds / improved varieties) and inappropriate livestock management practices (uncontrolled grazing) results in low productivity. This is a fundamental problem in an area where livelihoods depend largely on subsistence agriculture.

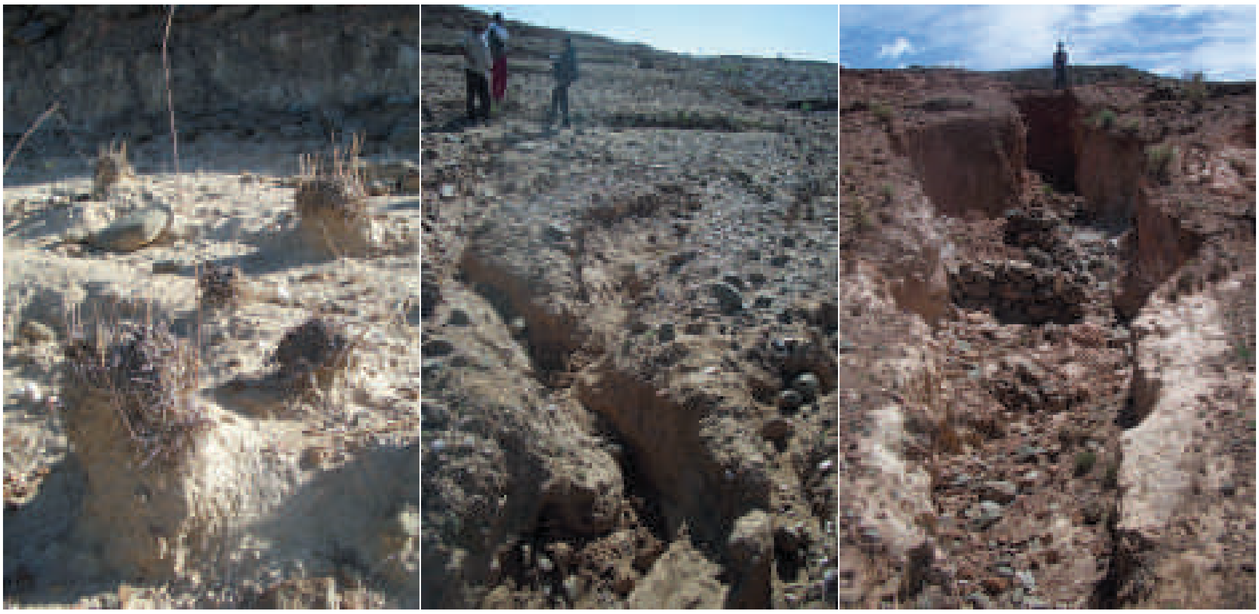


***Photo 8** Soil pillars stabilized by the roots of remaining perennial grass indicate the extent of sheet / interrill erosion (left); rill erosion caused by roadside runoff (centre) may develop into deep gullies (right) if not properly treated with SWC measures.*

During a PRA exercise and individual interviews[2], around 40 farmers identified and prioritised a number of key factors / constraints that they perceive to be the main factors limiting agricultural production. The following section lists and describes these factors. Problems and constraints specifically related to the establishment and maintenance of SWC measures are listed and explained under "Acceptance of SWC measures" (see page 106).

[2] The PRA carried out in 2005 involved key informants from the three villages, who were, in groups, asked to list problems and then, in a second step, rank them according to their importance (impact). The ranking was reconfirmed by farmers' statements made during individual interviews in 2004.

Main limitations of agricultural production (farmers' perception):

1. Shortage of rainfall / frequent drought / lack of irrigation water
2. Land scarcity, especially shortage of grazing land
3. Lack of manpower
4. Shortage of manure and decreasing soil fertility
5. Access to agricultural equipment and draught animals
6. Access to external inputs: improved seeds / artificial fertilisers
7. Marketing problems
8. Soil erosion / land degradation
9. Lack of maintenance of SWC measures
10. Importance of off-farm income
11. Land tenure / land use rights
12. Livestock management practices

Shortage of rainfall

The general shortage of rainfall as well as the high variability and unfavourable distribution of rainfall (erratic rainfall pattern) were stated to be the main constraints on agricultural production. According to the farmers, water availability is the main factor determining yields. Consequently, farmers recognise that both well-maintained bunds and rainfall have a crucial function. The rainy season often stops early, interrupting the process of ripening (in September). Water scarcity over long periods can cause crop failures. High-intensity rainfall events (heavy storms) lead to overflowing of SWC structures and flooding, thereby causing considerable loss of topsoil through surface erosion; floods destroy structures further downstream; waterlogging occurs, particularly in flat *shiebet* areas (especially problematic for beans). Hail causes a lot of damage, especially to susceptible crops such as vegetables.

Lack of irrigation water is considered a major limitation for agricultural production, as irrigation reduces the dependence on erratic rainfalls and is a prerequisite for the cultivation of cash crops such as potatoes and vegetables. The production of cash crops is an important means of income generation and thus relevant for poverty reduction. An additional source of water is needed also to improve the conditions for livestock.

Land scarcity

Land scarcity has also been stated as a major problem by the villagers. The farmland is highly fragmented into small plots: the average area of cropland per household is 0.86 ha. Population growth is increasing the pressure on the land. Most land is used for crop production, as this forms the basis of subsistence economy. As a result, grazing land for livestock is extremely scarce (on average 0.004 ha per household), and livestock is often left to graze uncontrolled on cropland, causing much damage to SWC structures. Land shortage is aggravated by several processes:

Infrastructure development: For the planned housing development in New Serejeka an area of 37 ha of cultivated land was taken away from the community and reserved for house construction (New Serejeka master plan). This area also included high fertility land. Farmers are worried that stones from SWC structures could be taken away for house construction. The new tarmac road from New Serejeka to Weki, between 15 and 22 meters wide (including embankment), cuts through the catchment occupying an area of approx. 5 ha. A total of 120 farmers lost part of their land to the road. Side-effects of construction work caused further damage and land loss: (1) An area of 3 ha used for preparing construction materials was rendered unsuitable for cultivation through removal of topsoil and compaction. (2) Further damage was caused by lorries and bulldozers entering cultivated fields to collect stones and earth for road construction, leaving behind wide tracks and breaking conservation structures. (3) No measures have been taken by the construction company to protect the agricultural fields from roadside runoff and runoff from outlet pipes, which has already caused serious rill erosion in many areas; (4) Heavy waterlogging occurs behind the road embankment on stretches where drainage infrastructure is missing. Despite these highly negative factors, farmers also state the advantages of the new road as an improved transportation facility.

Area closure for afforestation: Certain areas, totalling 75 ha of farmland, have been closed in collaboration with MoA afforestation programmes (e.g. Afdeyu, Kelkel zone).

Loss of land through conservation structures: Certain SWC measures – especially tied ridges – are not accepted by the farmers due to the area they occupy (tied ridges including the associated bunds cover up to 20% of the productive area). However, for most other SWC measures this is considered a minor problem, and many farmers are aware that SWC measures are absolutely necessary to protect the existing soil resources from further erosion and even restore some of the areas that were lost (e.g. due to gully erosion): "SWC measures do not take away land but conserve soil, and without them the land will be lost through erosion, which is the opposite" (local key informant, Afdeyu). With few exceptions, the loss of land through SWC structures is compensated by their positive effects.

***Photo 9**: Livestock openly graze on the residues of harvested crops. Although livestock is an important element of livelihood strategies, designated grazing land– such as the area in the background – is extremely rare.*

Lack of manpower

Lack of manpower has become a serious problem since the majority of the population actively involved in agricultural work had to leave their villages to join the national service. Female-headed households as well as elderly and weak people have problems carrying out heavy work such as ploughing and construction / maintenance of conservation structures on the field. They are forced to rent out their fields under a shared investment / shared benefit arrangement, which means that the person doing the work collects half of the production.

Shortage of manure and decreasing soil fertility

The limited availability of manure is another enormous problem. Due to lack of fuelwood, cattle dung is largely collected and used as fuel, which, in turn, seriously aggravates the shortage of manure to be applied on the fields. Furthermore, the system of open grazing massively complicates the gathering and specific application of dung (see "Livestock management practices" below). Alternative energy sources are not available or not affordable for the households.

Farmers directly link the problem of decreasing soil fertility to the constant lack of manure, as well as to the loss of topsoil through erosion. Another limiting factor of soil fertility is the shortage of water. *"Every year we get some konshim (artificial fertiliser) from the government at a cheap price, but you need to have enough water in order for this artificial fertiliser to be effective!"* Erosion further depletes existing soil nutrient reserves. The upper parts of the catchment and steep slopes are more affected by decreasing soil fertility due to advanced erosion processes, whereas in lower and flatter areas fertility may even increase due to siltation of eroded topsoil and fertiliser / residues that were washed away further upstream. In the end, low fertility results in low yields and thus leads to food shortage. *"Compared to our fathers' yields now the production is very low!"* (local key informant, Afdeyu).

Access to agricultural equipment and draught animals

Farmers often mentioned that due to high costs and a lack of financial resources they cannot afford agricultural equipment such as ploughing implements. Renting oxen for ploughing is likewise difficult for those farmers who do not own any. According to the wealth ranking carried out in 1999 (Virginia Dawod et al, 1999) more than 50% of all households do not own any oxen (see Table 3, page 26). Borrowing and mutual help between neighbours is an option , but nonetheless availability is limited and activities become retarded.

Access to external inputs (improved seeds / fertilisers)

Changes in the environment and changing farming practices have raised a need for external inputs in the local farming system. However, access to these inputs and their availability is very limited for the farmers in the study area. Subsistence-oriented production does not generate enough income to purchase them.

Farmers do not have access to high-quality seeds or improved varieties that produce high yields, are resistant to pests / diseases and suit the local conditions. Improved varieties (e.g. high-yield and resistant to disease) are hardly available. Although farmers can purchase fertilisers at a subsidised price from the MoA, they criticise the fact that these fertilisers are released only once a year, and sometimes not in time for application: *"We want it when the rain is falling (it should be available in June at the latest) because that's when we sow our fields and we apply this fertiliser together with our seed"* (local key informant, Afdeyu). The farmers' economic status and financial problems are closely related to the lack of alternative income generation.

Marketing problems

The local terms of trade are not favourable for the farmers: *"We sell our yields cheap and buy them expensive."* Since all crops are harvested at the same time, the market is flooded, and farmers are forced to sell their products at low prices. Storage of seeds is limited due to food shortages and – in the case of potatoes – due to the lack of facilities to store them for an entire year (problems of early germination or rotting). Better storing infrastructures or improved irrigation facilities would be one option to solve this problem.

Soil erosion / land degradation

There are different opinions on the severity of soil erosion. Most farmers were aware of the negative influence of soil erosion on yields (low germination rate, up to two thirds are lost). They also recognised that soil erosion is caused by improper management of their fields and conservation structures, and that the problem can be avoided to a great extent by means of hard work and adequate maintenance of existing SWC measures. Gullies and pipes were stated as obvious problems, causing the loss of productive cropland.

Accelerated siltation behind SWC structures is an obvious indicator of high erosion rates in the area. Heavy floods in the wake of storms are mentioned as a major reason for soil erosion. "*If we do not maintain our structures the soil is carried away to other villages!*" (Local farmer, Afdeyu). Other farmers considered soil erosion a minor problem, compared to the neighbouring villages, and point out that their land is comparatively well-conserved.

Lack of maintenance of SWC measures

Improper maintenance of SWC measures is the result of a broad range of constraints. Some of the major factors are: importance of off-farm income, lack of incentives, lack of manpower, attitude / awareness of the farmers, and insecure land use rights. For a detailed analysis of these problems and the reasons behind them, see "Parameters influencing acceptance of SWC measures" (page 108). Neglected maintenance leads to loss of topsoil, fertility decline and seed loss on fields, as well as siltation and overflowing in the area downstream – and worse, to breaching of structures, which, in turn, aggravates degradation processes.

Importance of off-farm income

In view of the difficult frame conditions farmers are facing, more and more households turn to alternative sources of income to meet their needs. However, this also means that less manpower is available for field work. Off-farm income includes wage labour, trade, etc.

Land tenure / land use rights

According to the current land tenure system, agricultural land is redistributed approximately every 7 years. This means that land use rights are temporary. Consequently, this system does not encourage any long term planning. Land users strive to get the maximum benefit out of their fields within the limited time, and they avoid investments that do not promise short-term benefits, especially towards the redistribution date. Efforts are concentrated on high-potential areas, while marginal fields are neglected, which leads to degradation of the production resource base.

Livestock management practices

Livestock management practices have already been mentioned in several different contexts. The main problem is the lack of specified grazing areas, resulting in the practice of uncontrolled grazing. This, in turn, has several negative impacts on crop production and fertility management: browsing livestock damages conservation structures (trampling); soil is left without a vegetation cover; manure is randomly distributed (selective application is not possible).

The importance of soil and water conservation measures

In summary, the study area is affected by serious land shortage. Population growth aggravates the pressure on natural resources, forcing farmers to use areas which are not suitable for crop cultivation. These processes result in land degradation and declining productivity, thus endangering the basis of livelihoods in subsistence farming. Additionally the land users are confronted with delicate bio-physical conditions, such as the semi-arid climate, high rainfall variability, and soils prone to erosion. Under these circumstances soil and water conservation measures take a crucial function in reducing land degradation and maintaining / increasing land productivity and, thus, ensuring the livelihoods of the people living in the area.

Table 7: *Mean yield in t/ha for different crops (1984-1998), Mayketin catchment, Afdeyu.*

	Barley	Wheat	Potato	Onion	Horse bean	Linseed	Maize
Yield above SWC structures	2.06	1.48	39.13	9.33	3.89	0.37	7.38
Yield between SWC structures	1.98	1.12	26.38	15.71	3.25	0.33	3.68
Yield below SWC structures	1.83	1.24	26.01	17.35	2.53	0.30	3.75

Source: Stillhardt et al 2002

The importance of SWC measures has been recognised long ago: local SWC measures have been practiced for generations. However, given the growing pressure on marginal areas and the necessity to intensify land use, they no longer suffice to cope with the fast changes of the environment. When the government recognised the problem, food-for-work mass campaigns came in as a new form of external initiatives to apply SWC measures on a larger scale. A variety of attempts have been undertaken to combat degradation processes, with varying degrees of success. In part III of this report a comprehensive documentation and assessment of technologies and approaches based on farmers' perception is provided.

Photo 10: *The effect of a simple contour bund on production: Crops are growing faster and denser in the area behind the bund where soil is accumulated and, most importantly, soil moisture is increased.*

A combination of three well-accepted local SWC measures: Level stone terraces, contour ploughing and deep furrows to divert water. Part 2 shows the diversity of SWC measures, both local and introduced, in standardised fact sheets and gives an overview of the approaches used to implement these measures. Emphasis is put on the assessment of acceptance of SWC measures and the underlying reasons for their adoption or rejection by farmers (Photo 11).

Assessment of Soil and Water Conservation Measures

SWC approaches

SWC measures

Acceptance of SWC measures

SWC approaches

Introduction

Definition of SWC approaches

A SWC approach defines the ways and means used to promote and implement a SWC technology and to support it in achieving more sustainable soil and water use. A SWC approach consists of the following elements:

- Different stakeholders: policy-makers, experts, technicians, land users, i.e. actors at all levels
- Inputs and means: financial, material, legislative, etc.
- Know-how: technical, scientific, practical

An approach may include different levels of intervention, from the individual farm, through the community level, the extension system, the regional or national administration, or the policy level, to the international framework (WOCAT 2003).

The present inventory distinguishes between two basic approaches:

Externally promoted projects / programmes – Implementation of introduced measures: Introduced SWC measures are promoted and implemented through external initiative, e.g. by development projects and programmes conducted by NGOs or government institutions. These agencies provide funding for activities and technical assistance and play a major role in decision-making. The use of incentives is common in government approaches. The participation of land users is often limited to the establishment phase.

Locally initiated approaches – Implementation of local measures: In this report, the term "local SWC measures" is used to describe practices which have been generated and developed by the local land users – be it recent innovations or old traditions. The definition also encompasses practices that were originally introduced from outside, but then underwent a process of adaptation and have since been fully adopted and used over generations by the land users. Furthermore, the term also includes local farming practices that have a SWC function (e.g. crop rotation), even though these are not considered to be SWC practices as such by the locals (see also Table 18, page 101, for further characterisation of introduced and local measures). The term 'local' can be considered a synonym to 'indigenous' or 'traditional', which are frequently used in this context.

For the mapping of SWC measures these two approaches were further divided into the following sub-categories:

- Local measures: traditional practices used over generations
- Farmers' initiative: spontaneous adoption / replication of originally introduced measures by farmers on their own initiative; innovations by farmers
- Introduced measures: promoted and introduced through external projects / programmes (e.g. campaigns)
- Adaptation: farmers' modifications of previously implemented measures according to individual needs

History of SWC in the study area

Soil and water conservation has a long history in Eritrea: People have been farming for thousands of years, and traditional conservation methods have evolved at the local level (RELMA 2002). Ancestors of Afdeyu farmers applied SWC measures individually, rather than in an organised or collective manner. The most widespread local SWC structures were high stone terraces that farmers built to conserve water and to make possible the cultivation of steep areas (e.g. around the settlement). These terraces were constructed at random, without the use of levelling instruments, and not exactly along the contour. Other traditional practises used for generations include agronomic measures such as crop rotation, fallowing, mixed cropping, contour ploughing, and compost / manure application.

During colonial times the Italians promoted some tree planting activities. Under the British Government, farmers were forced by law to establish terraces on their land, especially on steeper slopes, in order to counter soil erosion problems (local key informant 2004, personal communication).

Photo 12: *Traces of farming history in one picture: Traditional terraces (1) used for generations, a sisal fence (2), originally introduced by the Italian colonial administration and later fully adopted by the local land users, and finally, stone and earth bunds (3) as the most recent SWC measure implemented through government-initiated mass campaigns.*

Systematic implementation of SWC measures on a broad scale began after severe droughts in the 1970s and early 1980s, under the Ministry of Agriculture (MoA; expert key informant 2004, personal communication; Stillhardt et al 2002). Tremendous effort was put into the protection of soil resources: in the absence of applied research, but under pressure to act quickly due to rapidly progressing land degradation, measures like soil and stone bunds, hillside terracing, area enclosure and tree planting were implemented throughout the country. Conservation extension in this process was regarded as mainly a technical issue, largely ignoring the role and the traditional knowledge of the land users. Farmers were motivated to participate in SWC campaigns by means of incentives (first food-for-work, later cash-for-work; Herweg 1992).

In 1984, when research work was initiated at Afdeyu research station, a considerable portion of the cultivated area in the 177-ha catchment was already under conservation. The traditional, old bench terraces on the lower slopes had been supplemented by level stone bunds – albeit of low quality – on steeper cultivation land further uphill.

Upgrading work coupled with a new and more intensive soil conservation campaign took place in early 1986, during construction of the Afdeyu dam (which never became functional, as it broke in the same year). However, measures implemented during this campaign were only moderately efficient due to a lack of systematic maintenance (Stillhardt et al 2002).

After an interruption of campaign work due to lack of funds during the last years of the Independence War (1990/91), the Eritrean government launched an afforestation programme in 1992 which continued throughout the following years. Activities in the study area focused on the area outside the Mayketin catchment and included tree plantation, hillside terracing, and the establishment of micro-basins and check dams. The MoA branch office was moved from Adi Tekelizan to Serejeka (neighbouring Afdeyu). Apart from MoA extension service, the government also initiated new approaches to promote rural development: national service soldiers (national service campaign) and students on vacation (students' summer campaign) provided urgently needed manpower to rebuild infrastructure and extend soil conservation measures.

Another extensive MoA campaign was launched in 1999 to boost maintenance of existing measures and introduce large earth and stone bunds combined with tied ridges and check dams (see also Table 9 on page 42). The main purpose of this initiative was to protect the planned dam from siltation by efficient soil conservation in the whole catchment. To date, only about 6% of the study area remains untreated, mostly consisting of rocky or flat areas. Table 8 lists the approaches that have been taken in the study area since the 1990s with regard to the implementation of SWC measures:

Table 8: External and local SWC approaches

Externally promoted projects / programmes	**Leading institution / stakeholder**
Cash-for-work campaign (formerly food-for-work)	Government (MoA)
Students' summer campaign (*kremtawi ma'etot*)	Government (MoA, MoE, a.o.)
National service campaign (*wefri lim'at*)	Government
National development campaign *(warsay ykealo)*	Government
TOKER Integrated Community Development	TOKER (local NGO)
Integrated watershed development[1]	MoA/Danida
Locally initiated approaches	**Leading institution / stakeholder**
Village initiated approach	Local community
Individual initiative	Individual farmers

[1] not described in this report

Externally promoted projects and programmes

Cash-for-Work (CFW) campaigns

Responsibilities and decision-making

Campaigns are carried out by the MoA offices at Sub-*zoba* level, under close supervision of the Maekel *Zoba* MoA branch office. The headquarters (Forestry and Wildlife division) has the overall responsibility for monitoring and supervising project activities. Decisions on the choice of SWC measures to be implemented and the methods of implementation are made mainly by MoA representatives (expert key informant 2004, personal communication). Farmers do not participate in planning and decision making; their participation is largely limited to the implementation phase (establishment of SWC structures).

Target areas for SWC campaigns are prioritised according to the selection criteria of upper catchment development stated in Watershed Development Guidelines (expert key informants 2004, personal communication):

1. Importance of the area (high-potential dam sites and the related irrigation areas downstream are selected as priority areas; main purpose of SWC activities is to avoid siltation of dams)
2. Degree of degradation of agricultural land (status and dynamics of degradation)
3. Socio-economic conditions (poverty, food security)
4. Regional planning: five big catchments; implementation of SWC measures starts in the upper part of each catchment and continues downstream)
5. Availability of grazing land (hillside terraces and tree plantation implicate enclosure of the areas involved; this is only possible if the village has enough remaining land for grazing)

Mobilisation techniques

The MoA trains selected farmers (selection effected by the community) in soil and water conservation technologies, but also crop production, animal breeding, and other topics, depending on planned activities. Courses of 3 -10 days take place in the training centre ('Villaggio') in Asmara or sometimes in the form of practical on-the-job training in the field. Farmers like the training despite the fact that it is mainly theoretical. They become local SWC specialists, combining practical field experience and local SWC knowledge with new techniques. Once they have undergone training, the selected farmers work as promoters - so-called enumerators - in the villages and are responsible for passing on their knowledge and assisting their fellow villagers in SWC activities. Occasionally, some of them are even used as trainers in MoA training courses.

In Afdeyu, enumerators have been trained each heading a community group. They take the function of foremen, guiding and supervising the implementation of measures and providing technical assistance during campaigns. MoA technicians are present to assist activities on a daily basis during the initial phase of a campaign; later they visit the site once or twice a week.

Farmers have criticised the technical support provided by the MoA during implementation as being insufficient. Basically, support was limited to occasional supervision and post-construction corrections of layout failures or technical faults. According to farmers, the technicians should monitor activities more effectively and on a more frequent basis, because "poorly constructed measures may break and the erosion damage will be even bigger than before..." (Local key informant 2004, personal communication).

Implementation

Farmers are motivated to participate in SWC campaigns by means of financial incentives and, in the case of government-ordered afforestation programmes, cash compensation for the land they lose. Generally, more women than men have been participating in the campaigns, even in the years preceding the border conflict (1998–2000). The main reason for this is that men often look for casual labour during the dry period when there is less field work to be done (from January to May), while SWC activities are usually carried out during this very period of the year.

Photo 13: *Farmers construct stone and earth bunds in a cash-for-work campaign in Afdeyu. This approach is a prime example of externally promoted SWC initiatives.*

According to the original campaign approach known as food-for-work (FFW), incentives consisted of the provision of mainly wheat and oil. This was changed in the 1990s, when the MoA started to pay cash to farmers who participate in the implementation of SWC measures; this new approach is known as cash-for-work, or CFW. The wage is between 1.5–2 US$ (equivalent of 20–25 Eritrean *Nakfa*, rate 2006) per person day. The MoA has defined work norms for different measures (Expert key informant, personal communication 2006); these rates are currently being adjusted:

- stone bunds: construction of 8m per person day (at 25 *Nkf* / day)
- soil bunds / tied ridges: construction of 10 m per person day (at 20 *Nkf* / day)
- check dams: construction of 0.75m^3 per person day (at 20 *Nkf* / day)

Incentives guarantee active participation by the local community and at the same time provide a much needed source of income for the farmers. The provision of cash instead of food allows the beneficiaries to purchase goods according to their individual needs. In addition to incentives, seedlings (and partly also tools) are provided free of charge (Kohler 1999).

Table 9: Cash-for-work campaign 1999/2000 in Afdeyu (catchment treatment)

SWC measure	Planned	Realised
Stone and soil bunds	260 km (140 km soil bunds and 120 km stone bunds), covering a total area of 160 ha	204 km
Check dams	200 m^3; in gullies on cropland	225 m^3
Tied ridges / Micro-basins	6600 units; covering an area of 40 ha; construction in combination with soil bunds	6600 units
Tree planting	6600 seedlings; fodder, fruit and other multi-purpose trees; along field boundaries and on bunds	none
Grass strips on soil bunds	120 km; on soil bunds; several varieties (for stabilisation and fodder production)	6 km; only Vetiver (no fodder species)
Total area to be covered	160 ha	50 ha

Source: MoA Progress reports 2000

Table 10: C ash-for-work campaign 2006 in Afdeyu and Adi Jin

SWC measure established in Afdeyu	Realised
Stone bunds, earth bunds / tied ridges	7.3 km
Check dams (for sinkholes and waterways flowing from Adi Jin to Afdeyu)	153 m^3
SWC measure established in Adi Jin	**Realised**
Stone bunds, earth bunds / tied ridges	66 km
48 m3 of check dams (for sinkholes and waterways)	48 m^3

Source: expert key informant, personal communication 2006

Approach: In both campaigns, cash-for-work incentives were used: farmers were paid 1 US$ (13-15 Eritrean *Nakfa*) per day in 1999/2000. Later on, rates were increased (see above). Grass strips were planted by a students' summer campaign (1999/2000); farmers were not involved. No monitoring / evaluation was carried out to assess the impact / effectiveness of the measures and their adoption / acceptance by farmers.

Maintenance

During the last SWC campaign in the study area, the first week was reserved for maintenance of existing SWC measures before the construction of new measures started. The MoA has set up directions to protect implemented measures. Regarding structural measures these include the following rules:

- Dismantling of introduced structures is not allowed
- Maintenance should be carried out individually (each farmer on his own fields)
- Control mechanisms should be arranged at the village level, e.g. through local by-laws; rules set up at the village level (e.g. by elders) can help control maintenance; alternatively, one of the farmers can be appointed to do the monitoring against payment
- Trees in the afforestation areas are also protected by law and guarded by a village member. Selective cutting is allowed upon permission from the MoA.

However, these directives are not effective enough to guarantee proper maintenance. Maintenance of SWC measures introduced in campaigns therefore remains a critical issue. From an external point of view, there are two major problems that need to be solved:

1) Predominance of externally-sponsored and externally-initiated approaches creates an attitude of expectation ("receiver mentality") among the farmers. SWC activities are perceived as a paid extra task in addition to everyday field work. This effect is coupled with the problem of maintenance. If farmers are primarily motivated by payments and perceive SWC as an externally-initiated activity, they will not develop a feeling of ownership regarding the implemented measures. Since incentives cease once the measures are put in place, this will result in the abandonment of maintenance.

2) With regard to communal land, i.e. all areas closed for afforestation, an additional problem is that nobody feels responsible to maintain SWC measures because there are no direct individual benefits (Kohler, personal communication 1999).

Monitoring / evaluation

MoA extensionists assess the condition of implemented SWC measures during sporadic field visits, e.g. after the rainy season. Discussions with farmers help assess problems and constraints (e.g. lack of grazing land / uncontrolled grazing, which is an important limitation for successful implementation of enclosures and grass strips). Annual statistics on implemented measures are recorded in activity reports. Systematic monitoring activities and evaluations of performance or impacts of SWC measures have not been carried out in Afdeyu (Expert key informants, personal communication, 2004).

Farmers' evaluation of SWC campaigns

Many farmers, including the "hard workers" (those who are actively and individually engaged in SWC activities on their own fields, see also "Farmers' perceptions", page 108), reckon that campaigns are important. A major reason for this is that campaigns also motivate farmers who otherwise do not engage in SWC. Thanks to campaigns, SWC measures are constructed and maintained evenly throughout large consistent areas, filling the gaps left by farmers who are not able to carry out SWC work or who fail to do so because they are unaware of its importance. Income was often mentioned as a major reason for participation in campaigns: "Our main objective is to have our daily bread. That's why it is important to have a source of income. Later on you realise that it is useful for your land too" (local key informant). Farmers actually perceive campaigns as a win-win situation: the land is conserved and at the same time economical problems are alleviated. Nevertheless, farmers also stated several problems related to CFW campaigns. Table 11 gives an overview of the approach's strengths and weaknesses as perceived by the farmers.

***Table 11:** Strengths and weaknesses of CFW / FFW campaigns (farmers' perception)*

Strengths	Weaknesses
Source of income: food or cash from incentives helps to reduce poverty and improve food security **Efficient SWC:** CFW / FFW campaigns result in establishment of well-designed, efficient SWC measures; they contribute to achieving sustainable land management; land becomes fertile **Reduced out-migration:** CFW / FFW campaigns help to prevent farmers from leaving the village to look for off-farm income and thus from neglecting field activities (field activities are crucial to conserving the land and keeping it fertile; fertile land is perceived by farmers as their "life insurance") **Collective work:** CFW / FFW campaigns encourage collective work; heavy and labour-intensive activities such as constructing check dams, rehabilitating collapsed terraces, etc. cannot be carried out by single farmers **Area coverage:** CFW / FFW campaigns cover the land of all farmers, including those who are not capable of field work (old or sick people and female-headed households) as well as those who are not motivated; they also cover uncultivated and communal areas; thus ensuring conservation of both poor and fertile land **Technical assistance** guarantees more accurate alignment of structures along the contour	**Inexact construction:** poor quality of implemented structures; measures are not built carefully enough for the following reasons: 1) the primary motivation for participating in a campaign is to receive incentives and not to conserve the land; 2) poor motivation to work on land other than one's own **Consequences of inexact construction:** poorly built structures are not stable enough; they can break, thereby even aggravating erosion damage **Lack of site-specific solutions** **Individual modification** of introduced measures is not allowed (e.g. to move bunds) **Technical assistance:** there is a lack of information regarding the purpose and benefits of certain measures during implementation; technical assistance is provided but should be enhanced

Students' summer campaign *(kremtawi ma'etot)*

The Tigrinya term *ma'etot* is generally used for voluntary group work. Every year, Eritrean high school students throughout the country work for afforestation and soil conservation campaigns during their summer vacations. Based on the original idea of the students' summer campaign promoting and accelerating the national reforestation programme, well over 60% of the work carried out by the students goes into combating desertification through participation in environmental conservation and development activities (www.unccd.int/cop/reports/africa/national/2002/eritrea-eng.pdf). The students' summer campaign programme was launched in 1994 and is coordinated by a committee involving the (Ministries of Education, Agriculture, Transportation, Construction, and Health). Participation is mandatory for a period of 30–40 days per summer; apart from some pocket money there is no payment (expert key informant 2004, personal communication).

Activities take place during the rainy season (July–August). Students are mainly involved in planting, while terracing and pitting is mostly done by local farmers or by soldiers from the national service campaign (see below). Nevertheless, students also participate in the construction of SWC structures (e.g. gabion check dams) and help farmers do field work (e.g. weeding). Teachers are instructed by the MoA and then guide their students during implementation. Additional technical assistance is provided by the MoA.

In the study area, students were involved in afforestation and the planting of grass strips on bunds (expert key informant 2004, personal communication).

National service campaign *(wefri lim'at)*

Wefri lim'at is a one-month SWC campaign initiated by the government that focuses mainly on tree planting, check dams, and the establishment of hillside terraces. The work is done in groups by people in the national service (expert key informant 2005, personal communication).

As an integral part of the country development plan, the first national service campaign was organised in May 1998. It involved broad participation and financial contributions by the Eritrean population. 25,893 people from the national service were deployed on 10 degraded catchments for three weeks. The work accomplished during this campaign was both astonishing and impressive: 400 ha of hillside terraces, 167 km of check dams, and 20 ha of micro-basins were constructed, and 439,408 pits for planting seedlings were prepared. (www.unccd.int/cop/reports/africa/national/2002/eritrea-eng.pdf). In 1998, the national service campaign was also active in Afdeyu (e.g. afforestation and hillside terracing in Kelkel area) and Adi Jin.

Photo 14: *Women returning from collective maintenance of SWC structures – an assignment in the context of the national development campaigns.*

National development campaign *(warsay ykealo)*

Warsay ykealo is the latest type of government-initiated campaign. It was launched during the war in 2000, with the aim of promoting development and the reconstruction of infrastructure (roads, buildings) and conservation measures throughout the country. Every Eritrean citizen (including non-residents) has to contribute in terms of labour or financial resources.

Under both national development and national service campaigns, activities were mostly carried out by soldiers doing national service. Participation was obligatory, and there was no payment or other incentive. Work was carried out in groups at different administrative levels (in the study area mostly at village level). (expert key informant, personal communication 2004).

TOKER Integrated Community Development

TOKER Integrated Community Development (TICD) is a local Eritrean NGO registered with the Eritrean Relief and Refugee Commission. It started functioning in Serejeka Sub-*zoba* as a project under the MoA, undertaking developmental activities since 1994. TOKER takes an integrated approach to developing the agricultural sector.

The aims of the TOKER Land Husbandry Project are to increase agricultural productivity, income and the general wellbeing of the population. TOKER's methodology is set up to empower village committees, to identify problems and jointly elaborate a plan to increase agricultural production on private and communal plots. The project focuses above all on strengthening the target groups and organisation capacities. Apart from agricultural production and soil and water conservation, the programme activities include infrastructure development (houses, storage, drinking water supply), health and sanitation, mother and child care, and income generation for women.

In order to increase the government's capacity to support such a programme, government (MoA) personnel receives training on various topics, e.g. participatory planning methods.

TICD has achieved much in the training of farmers, who, in turn, play an important role in training other farmers and in implementing new agricultural techniques, including complementary production systems such as vegetable cultivation, apiculture, and poultry keeping. Upon request of the MoA, TICD has contributed to small-scale irrigation projects. Communities in the project areas will develop village structures that can take responsibility for managing this work (general development committee, specialised professional groups). An active involvement of men and women in decision-making on all project activities is an important principle of the approach (UNCCD 2004).

Locally initiated approaches

Village-initiated approach (collective work in *coms*)

Each village has a development committee consisting of three local leaders who are assigned to manage and coordinate the following activities: 1) agriculture and forestry; 2) social services and sanitation; and 3) land issues and property. The three representatives are elected by the village; in collaboration with the village administrator they present their ideas to the village assembly for approval. If accepted by a majority, the proposed activities are carried out; all village members are expected to participate.

Collective work is usually carried out in predefined groups, the so called *coms*. The population of Afdeyu, for example, is divided into 6 *coms*, comprising 45–60 households each. The *coms* have different mandates, the most important being the organisation of the land re-distributions. Maintenance of SWC measures (especially labour-intensive activities such as gully reclamation) is sometimes carried out collectively before the re-distribution; however, this depends entirely on the agreements made among the members of the *com*. No incentives are provided. One member per household is expected to participate, although there are no consequences in case of absence.

In practice, collective conservation activities are very rarely carried out. This is true even for the rehabilitation of fields with heavy gully formation (which is beyond the capacity of any individual farmer) and also with regard to helping disabled persons. Generally, there is a lack of collaboration for agricultural activities, whereas group work appears to function well with regard to house construction or other non-agricultural activities (where the beneficiary usually comes up for food and drinks for the participating villagers). As a potential cause for this, farmers mentioned the incentive-driven campaigns: locals get used to receiving incentives for collective work and are no longer willing to do it for free. (This effect is increased by the fact that incentive-driven campaigns are also organised within the *coms*). Moreover, the so-called "hard workers," who invest considerable labour and time in SWC activities on their own fields, are not prepared to support their "lazy" neighbours.

A village-initiated approach for hillside terracing and tree planting

A unique and exceptionally successful case of a village-initiated approach took place in Afdeyu in 1996 and is described by Iyob Zeremariam in his paper entitled "A village initiated approach for implementing hillside terracing for tree planting technology" (Iyob Zeremariam 2000, unpublished):

At a very small scale, farmers took their own new approach to implementing terraces for tree planting. Marking of contour lines was done collectively, whereas terracing, pitting and planting was carried out individually by each farmer on his own fields. Seedlings were collected individually from the Ministry of Agriculture nurseries, free of charge. Once the area was terraced and planted, open grazing was prohibited and the area enclosed. Protection of enclosures (afforestation areas), maintenance of the structures, and general post-establishment operations (such as repitting, replanting, weeding, cultivation, irrigation, and thinning) are the responsibility of each individual farmer. Nevertheless, in most instances protection is organised collectively: each household contributes (in cash or in kind) to hire a guard. Farmers are free to use the trees they planted individually, according to their needs; this is the basic motivation for participating at all. However, they have to ask permission from the MoA to cut trees to ensure maturity of the tree and proper cutting techniques (which allow regeneration/sprouting).

Individual initiative

Individual initiative is the most common local approach to construction and maintenance of conservation measures. Only few farmers have undergone formal training, but all of them have learnt about SWC in one way or another:

- Experience gained through participation in SWC campaigns
- Local SWC knowledge passed on from generation to generation
- Experimentation (leading to local innovations)
- Observation and replication of introduced measures and local innovations

Individual initiatives include local innovations, maintenance, modifications or replications of SWC measures on household level without external incentives.

Conditions for local innovations are favourable where land use rights are secure and external influence is low. In the western part of Gedena zone in Afdeyu, for example, land has not been re-distributed for decades and has not been included in campaigns. This has led to the development of a rich diversity of SWC measures, including stone terraces, stone bunds, diversion bunds and ditches, drainage systems, and mobile bunds, based on the initiative of individual farmers, who constructed these measures without any external support. However, also in other areas of the village farmers complement existing structures with additional measures in order to improve fertility management and water availability where necessary.

Maintenance (individual)

Maintenance of any SWC measures – introduced or local – depends on the commitment of the individual farmers. The motivation to keep up maintenance of SWC structures is high for structures that farmers built on their own initiative, whereas introduced measures are often poorly accepted and, consequently, poorly maintained.

There are three types of individual maintenance:

1) Maintenance integrated into everyday field work, carried out in combination with other field activities such as manuring, ploughing, sowing, etc.; e.g. adding stones and soil to increase the height of the bunds;

2) Spontaneous maintenance carried out according to needs during the rainy season, e.g. immediate assessment and repair of damage after heavy rainfall events;

3) Systematic maintenance carried out once a year (as an 'extra activity'), usually during the dry season (January–May) because the work load is smaller then and farmers want to prepare for the high runoff of the rainy season; requires approximately 5 days of labour; involves repair of broken structures, increasing the height of structures (since siltation on the upper side is a continuous process), and establishment of new structures (e.g. in places where gullies have started to develop).

Systematic maintenance is enhanced every four years, during *tsig'e* (first year of a 4-year crop-rotation and fallow cycle), and particularly in the first year following a land re-distribution, when most farmers make a special effort towards individual maintenance of SWC structures. In these years, most of them apply fertiliser and are thus particularly interested in preventing nutrients from being washed away by floods. In the second and especially in the third year of a cropping cycle (before the field is left fallow), farmers tend to decrease maintenance activities. Moreover, towards the end of the 7-year period of ownership maintenance activities are neglected because the field is to be handed over to another owner.

Generally, maintenance activities are more frequent in Gedena zone, where plots are fertile and under intensive use. Moreover, Gedena zone is located close to the village.

Photo 15: *"You eat what you invest": stone bunds built on farmers' own initiative improve water availability and consequently crop yields.*

Individual maintenance activities are strictly related to individually used cropland areas, whereas maintenance of SWC measures on communal land (e.g. upper catchments, afforestation areas, uncultivated/marginal land) requires collective work and is therefore hardly ever realised by farmers without external incentives.

SWC measures

Introduction

Definition of SWC measures

SWC measures are practices at the local level that help restore, maintain or enhance the productive capacity of the land in areas affected by or prone to degradation. SWC measures aim at a sustainable use of natural resources, ensuring their ecological, economic and social functions and benefits in the long term. SWC measures can be further specified (WOCAT 2003, partly adapted by authors):

SWC measures focus on the following **land use types**:

- Cropland
- Grazing land
- Forest and woodland
- Mixed land (e.g. agroforestry)

SWC measures address the following **types of degradation**:

- Soil erosion (by water and wind)
- Declining soil fertility and organic matter content
- Deterioration of soil structure (sealing, crusting, compaction)
- Loss of soil moisture, i.e. water availability (through evaporation and runoff); aridification
- Degradation of vegetation
- Off-site degradation (e.g. downstream flooding, siltation of reservoirs, etc.)

The main effects and **technical functions** of SWC measures are:

- Improvement of ground cover
- Reduction of slope angle / slope length
- Enhancement and recycling of nutrients and organic matter
- Improvement of soil structure
- Control raindrop splash
- Retain / retard dispersed and concentrated runoff (by avoiding detachment of soil particles and encouraging their deposition and sedimentation)
- Increase of soil water storage (e.g. by increasing infiltration, reducing evaporation)
- Water harvesting; and water spreading / diversion

SWC measures comprise permanent, semi-permanent or annually applied measures, which can be categorised into:

- **Agronomic measures**: are usually associated with annual crops; are repeated routinely each season or in a rotational sequence; are of short duration and not permanent; do not lead to changes in slope profile; are normally independent of slope; do not require high labour or financial investments; are often related to fertility management. Typical examples are: manuring, intercropping, contour ploughing, mulching.
- **Vegetative measures**: involve the use of perennial grasses, shrubs or trees; are of long duration; often lead to a change in slope profile; are often zoned on the contour or at right angles to wind direction; are often spaced according to slope. Typical examples are: tree planting, hedge barriers, grass strips.
- **Structural measures**: often lead to a change in slope profile; are of long duration or permanent; are carried out primarily to control runoff, wind velocity and erosion; often require substantial inputs of labour or money when first installed; are often zoned on the contour / against wind direction; are often spaced according to slope; involve major earth movements and / or construction with wood, stone, or other materials. Typical examples are: contour or diversion bunds, terraces, micro-basins.
- **Management measures**: involve a fundamental change in land use; involve no agronomic and structural measures; often result in improved vegetative cover; often reduce the intensity of use; do not require high labour or financial investments. Typical examples are: land use change, area closure, rotational grazing.

Photo 16: *A nice example showing the efficiency of a well-maintained structural measure: an area which used to be seriously affected by gully erosion has completely recovered after implementation of a series of closely spaced stone walls. The levelled area is under cultivation again.*

According to the **approach** (for definitions see page 38) taken to the implementation of SWC measures we can differentiate between:

- local measures
- introduced measures

In the study area, local and introduced measures are rarely applied separately on clearly demarcated units, i.e. there is no clear line between them in the field. Rather, they occur in complex combinations within the same conservation system: for example, a new stone and earth bund might be built on the edge of a silted traditional terrace, or introduced grass strips might reinforce a local soil bund. This often makes it difficult to differentiate between traditional and introduced structures.

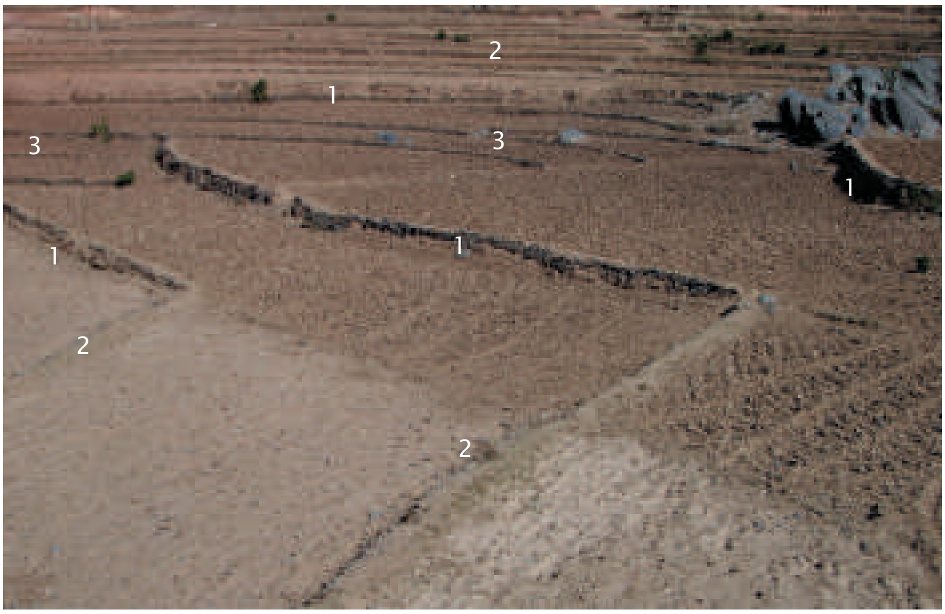


Photo 17: *A complex combination of different SWC measures and approaches: Traditional terraces along field boundaries (1) are complemented by introduced bunds along the contour (2). The additional structures in between (3) have been recently implemented on individual initiative.*

Aside from the spatial dimension there is also the aspect of time: Colonial administrations recognised the problem of soil erosion early on, and soil conservation measures started to be implemented in farming areas under the British rule. In the meantime, some of these originally introduced SWC measures have long been adopted, adapted to the local conditions, and incorporated into local farming systems to a degree that today's farmers consider them local. Comparative tables on general characteristics and technical aspects of local and introduced measures in the study area are presented on pages 101 and in the Annex on page 197.

Fact sheets – some explanations

The following chapter ("Inventory of local and introduced SWC measures") provides a comprehensive documentation of the local and introduced SWC measures identified in the study area. It is not the aim of this report to provide a technical manual on SWC measures, but to show the diversity of options applicable in the Central Highland Zone, including their problems and benefits as perceived by farmers, and to indicate possible reasons for the acceptance of SWC measures. Where not specifically mentioned, sources of information are the local key informants.

Each measure is documented in a standardised way on a 2-page fact sheet. The box on page 51 introduces the format used. The order of appearance of the SWC measures was determined based on the following criteria (starting with first priority):

1) approach (local, introduced)
2) SWC category (structural, vegetative, agronomic, management)
3) Land use type (cropland, grazing land, forest)

In a PRA exercise each documented SWC measure was ranked by the local land users with reference to four topics:

- Acceptance
- Area coverage
- Condition
- Efficiency

The **Acceptance** of a specific SWC measure is measured by the degree of spontaneous adoption by the local farmers or by the rate of replication on farmers' own initiative. For more definitions and criteria of acceptance see "Acceptance of SWC measures", page 106.

Area coverage refers to how widely or how often a SWC measure is practised in the study area. It is also applicable to SWC measures that are confined either locally (to hotspots or other small areas, e.g. check dams) or temporally (e.g. agronomic measures, such as manuring). Area coverage has also to be seen in relation to the applicability of a specific measure: In the case of check dams for example, area coverage is not the total number of check dams in a given area, but this number *in relation to gullies occurring* in the area, i.e. the proportion of gullies treated with check dams to untreated or otherwise treated gullies.

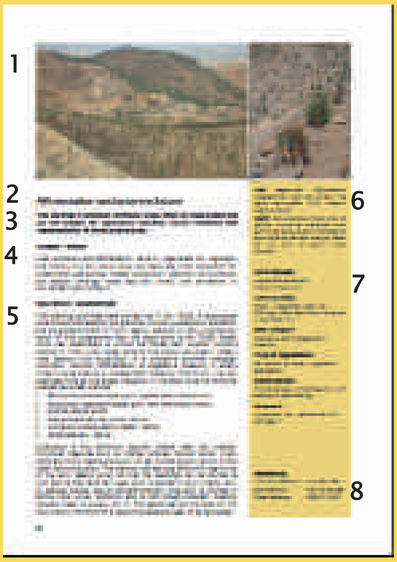
The current **condition** of the SWC measure indicates the level of its maintenance. The level of maintenance of a measure depends on a variety of different factors (see "Condition of SWC measures and land degradation", page 158). Again, the level of maintenance can also be an indicator for the acceptance of a measure. Since the condition of a measure can vary considerably depending on the site of application, the ranking indicates the average condition of a measure throughout the study area. The condition is only assessed for permanent or semi-permanent measures that are intended to remain on the land over several years or longer.

The **efficiency** regarding soil and water conservation is ranked based on the following criteria: 1) potential to conserve soil; 2) potential to conserve water; 3) potential to increase production

A more comprehensive assessment of these aspects, including analytical tables and comparisons between the measures, is presented in the next chapter (see "Acceptance of SWC measures", page 106 et sqq.)

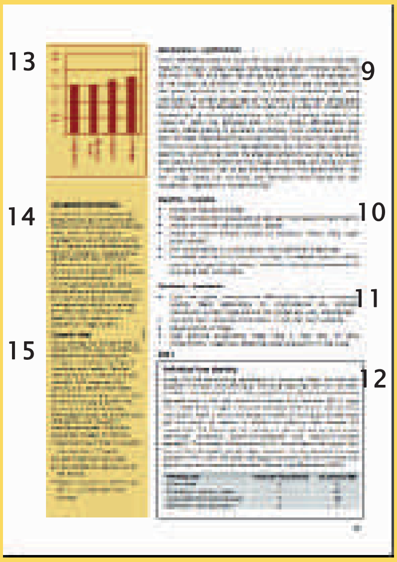
Structure of the fact sheets

The fact sheets are presented in a standard format with the following structure:



Page 1

1) **Photos:** overview and details of the measure
2) **Name of the SWC measure**
3) **Definition:** short description of the measure
4) **Purpose / effects** of the measure
5) **Description / establishment:** Design, establishment steps, etc.
6) Photo **captions**
7) **Information and specifications** on…
   - the **local name**(s) of the measures (in Tigrinya)
   - the **land use type** where the measure is applied
   - the **conservation category** of the measures (structural, vegetative, agronomic, management)
   - the **type of degradation** addressed
   - possible **combinations** with other practices
   - the **approach** used (for implementation)
8) **References:** local key informant(s); geo-reference; photo reference



Page 2

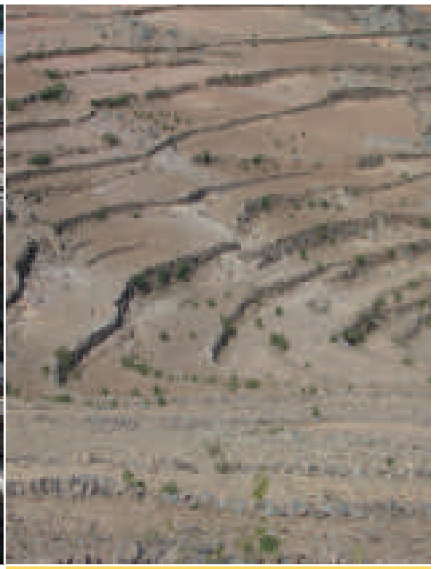
9) **Maintenance / modifications**: Maintenance steps, local adaptations (on page 1 or 2)
10) **Benefits / strengths**
11) **Problems / drawbacks**
12) Additional information in **Boxes, Tables or Figures** (where available and relevant)
13) **Graph:** illustrates the acceptance, area coverage, condition and efficiency of the measure (as assessed by farmers); definitions see page 50;
14) **Acceptance** of the measure; and the reasons behind
15) **Expert's view:** comments by external specialists, from national institutions (NARI, MoA); for introduced measures only

Inventory of local and introduced SWC measures

Table 12: Overview of local and introduced SWC measures and their classification

Local SWC measure	Category	Land use type	Purpose (farmers' perspective)	page
Traditional stone terraces	structural	cropland	extension of arable land (cultivation of steep areas); soil and water conservation	53
Earth bunds (+ natural grass strips)	structural (+vegetative)	cropland	delimitation of plots (field boundaries)	55
Mobile bunds	agronomic / structural	cropland	water distribution; fertility management	57
Water diversion and drainage systems	structural (+agronomic)	cropland	water distribution; water conservation	59
Small dams[1]	structural	not specified	water harvesting	--
Gully / pipe reclamation	structural	cropland	reversal of loss of productive land (levelling); soil and water conservation	63
Live fences	vegetative	residential area / cropland	fencing; soil conservation	65
Permanent area enclosure; natural regeneration of vegetation	vegetative / management	forest / grazing	vegetation conservation; wood production for fuel, construction, etc.	67
Crop rotation	agronomic	cropland	fertility management; pest control	69
Fallowing (temporary area enclosure)	agronomic	cropland	fertility management	71
Local ploughing system	agronomic	cropland	seedbed preparation; soil conservation; water harvesting / conservation	73
Intercropping / mixed cropping	agronomic	cropland	fertility management; reduced risk of crop failure	75
Compost / manure application	agronomic	cropland	fertility management	77
Stone mulching	agronomic	cropland	moisture conservation, avoid loss of topsoil	79
Furrow irrigation[1]	agronomic	cropland	production increase	--
Introduced SWC measures	**Category**	**Land use type**	**Purpose** (experts' perspective)	**page**
Stone and earth bunds on cropland[2]	structural	cropland	soil and water conservation; reduction of downstream dam siltation	81
Tied ridges	structural	cropland	in-situ water conservation (avoid lateral flow); soil conservation	83
Fanya juu [3]	structural	cropland	soil and water conservation	85
Stone check dams	structural	all land use types	reduction of gully erosion, rehabilitation of gullies	87
Gabion check dams [4]	structural	cropland / grazing land	stabilisation of big gullies	--
Hillside terraces	structural	forest	soil and water conservation on steep slopes (for tree plantation)	89
Micro-basins (for tree plantation)	structural	forest	water harvesting for tree plantation; soil conservation	91
Afforestation and area closure (+ cut-and-carry)	vegetative / management	forest	vegetation regeneration; soil cover improvement; fodder production	93
Agroforestry [5]	vegetative	cropland	multi-purpose (depends on species)	95
Grass strips [5]	vegetative	cropland	soil and water conservation; fodder	97
Fertiliser application	agronomic	cropland	fertility management	99

[1] Not documented in this study (no fact sheet)
[2] Includes stone bunds, earth bunds, and combined stone and earth bunds (mostly combined!)
[3] Applied outside study area only (Adi Asfeda)
[4] Gabion check dams (identified in Kuasien and Tsehaflam) have not been documented in this study due to a lack of well-established examples and unavailability of local key informants
[5] Applied on a very small area inside the study area, mainly applied outside study area



Left: Traditional level bench terraces with high stone risers make it possible to intensively use the steep slopes around the settlement of Adi Jin.

Right: Local SWC measures are typically constructed by individuals on individual plots; therefore they often do not form continuous barriers against erosion. Individual terraces are linked and gaps are closed during SWC campaigns.

Traditional stone terraces

Benches or forward sloping terraces, usually with high stone risers; developed over decades; often laid out along traditional plot boundaries and not necessarily along the contour, often staggered.

Purpose / effects

Increase in arable land (effected through levelling of steep uncultivated land); reduction of runoff and erosion control; moisture conservation; increase in soil fertility (through siltation of eroded topsoil).

Description / establishment

Farmers in the area have a long tradition of building in stone (stone walls for traditional houses, fences, etc.). Stone terraces were built even before British colonisation. The structures are established individually and usually follow old field boundaries, which is why they are often staggered and not necessarily laid out along the contour. Traditional stone terraces are typically found in Gedena (intensively used area near village, mostly on steep slopes) and in valleys or on mountainous cropland. The terraces often reach a considerable height due to continuous enhancement, but also because they must be wide enough to allow for easy turning of oxen ploughs. Possibly the oldest existing traditional SWC structure, its construction method is poorly documented. Farmers state that there are two different construction methods, even though in many cases they were probably combined. These are:

Cut and fill: 1) Establish foundation to a depth of 0.25–0.5 m. 2) Build the stone wall, placing large stones at the lower part of the structure so that they are inclined towards the slope, and small stones at the upper part and in between big stones. Width: 1–1.5 m at the bottom, narrowing towards the top. Height: not specified, varies between 1–5 m, rarely higher than 5 m. Spacing of the terraces varies according to slope, soil depth, soil fertility and expected runoff. In sloping areas and on non-fertile and shallow soils the spacing is narrow (Freweyni and Helen 1999). 3) Cut and fill: dig soil from the upper part and transfer it to the lower part (with support from animal passing along the future terrace to move loosened soil down the slope towards the wall, at the same time compacting it).

Gradual development: 1) Start with a simple stone bund. 2) Gradually enhance the riser, while a terrace slowly forms through continuous siltation.

Local name(s):

Deldal / mdldal (general term for terrace / bund);
medebawi zala (bench terrace);

Land use type:

Cropland

SWC category:

Structural measure (permanent)

Type of degradation:

Surface erosion by water

Combinations:

Drainage furrows, contour tillage

Approach:

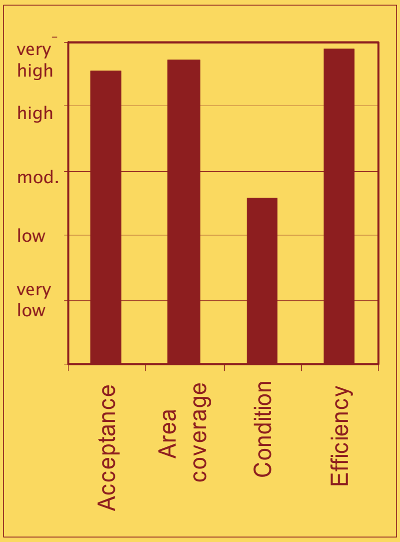
Indigenous; has been applied for generations; individual implementation

References:

Local key informant: No. 36, 67
See Table 45 , page 185/186

Geo-reference: Pt. 1–7
See Table 47, page 195/196

Photos: SLM Eritrea photobase



Acceptance by farmers

Farmers in the study area have inherited the traditional stone terraces from their ancestors. The structures have been maintained and enhanced for generations and are still widely maintained nowadays, predominantly in valleys and on intensively used steep slopes near the villages. The terraces are adapted to the local conditions and to the existing farming system. The condition of the structures is generally moderate, although there is great spatial variance: terraces close to settlement areas (Gedena) are usually in good condition, whereas structures in marginal, steep areas are in an advanced stage of deterioration. This is due to various reasons:

- Farmers abandon fields – often located in marginal, steep areas – where fertility has declined; therefore they also abandon maintenance of SWC structures on these fields.
- Traditional terraces are sometimes abandoned by order during SWC campaigns because they are not aligned along the contour. A new bund is usually built at the base of the old terrace.
- Restoration of a collapsed terrace section requires high labour input which can sometimes not be achieved individually. Labour inputs also depend on the accessibility of a site.
- Limited availability of stones to gradually build up the terrace riser.

Maintenance / modifications

Stone terraces require annual maintenance. The stone riser needs to be gradually enhanced due to constant accumulation of soil behind the structures (siltation), and constant repair work (e.g. replacement of fallen stones) is necessary because frequent passing of animals and people tends to damage terraces, particularly in areas near the village (Gedena). Old terrace risers are, in many cases, no longer reinforced with stones, particularly at the base: stones come loose and fall off due to erosion / water movement, or, in case of low availability on the field, are removed from the lower part of the riser and used to increase the terrace wall. The fact that traditional terraces are not laid out along the contour can lead to lateral flow and concentration of runoff and overflowing at the lowest point. These processes lead to breaching, collapse and pipe erosion if not counteracted by levelling work. During maintenance activities in campaigns, the alignment of old terraces is abandoned where they do not follow the contour, and a new stone bunds is built at the base of the terrace.

Modification observed in the field: One innovative farmer transferred clods overgrown with grass from a combined stone and earth bund to reinforce the edge of a newly rebuilt stone terrace.

Benefits / strengths

- Converts marginal land (hillsides) into cultivable, arable land; reduces land scarcity
- Protects efficiently against erosion; good conservation of soil and applied fertiliser
- High increase of water availability
- Increases soil fertility / crop yields, especially near the edge of the terrace (siltation of eroded topsoil)
- Field is cleared from stones and the slope angle is reduced, resulting in increased workability and suitability for various crops
- Reduced risk of crop failure
- As a traditional measure it was constructed carefully by individual farmers; if well-maintained, stone terraces are stable and durable

Problems / drawbacks

- Requires high labour input; men are absent due to national service and heavy work cannot be done by women / old people
- Drainage of excess water is not ensured, sometimes leading to overflow
- On clayey soils, bench terraces can cause waterlogging
- Lack of (large) stones (to construct a stable stone wall) in certain areas
- Terraces are often staggered / not continuous
- Terraces are frequently *not* aligned along the contour; this causes risk of overflowing and breaching and leads to difficulties in the implementation of introduced measures that follow the contour
- Terraces are old and often very high; therefore
  - they are partly unstable (if poorly maintained)
  - they require frequent maintenance (to avoid overflowing and breaching and to keep up with siltation)
  - the risers occupy a lot of space (if not properly built with a stone wall)
- High terrace risers provide a habitat for rodents; canals dug by rodents are assumed to induce pipe erosion.

__Left__: Local earth bunds developed from field boundaries that remained unploughed over generations. These boundaries often run in straight lines and do not necessarily follow the contour. Introduced contour bunds clearly cross these traditional boundaries.

__Right__: Natural grass barriers develop on local earth bunds. Hardly visible during the dry season, they nonetheless help stabilize the bunds and provide fodder for livestock.

Earth bunds

Soil embankment marking the boundary between two properties; developed over years on the small unploughed strips of land separating two neighbouring fields; frequently not aligned along the contour

Purpose / effects

Originally, the main purpose of earth bunds was not soil and water conservation but simply the demarcation of properties. Nevertheless, farmers are aware of the conservation effect of these "spontaneously grown" bunds.

Description / establishment

There are two types of earth bunds which may be identical in appearance, but serve a different purpose and have developed differently.

1) **Boundary earth bunds** mark the boundary between two properties and are not actively built by farmers, but develop over years on the small unploughed strip of land separating two fields and are consolidated by addition of weeds together with clods of earth from the cultivated fields. These bunds are permanent structures. They are often laid out in straight lines and not necessarily along the contour. Since boundary earth bunds are never ploughed, they are often covered with natural grass strips. Some native grass species found in the study area are:

- *Meker*[3]: High, quite dense in rainy season, palatable, good for SWC; can be multiplied by removing and planting tillers as well as by direct seeding
- *Lahu*[2] / *gaja*[2]: Shorter and stronger than *meker*, less palatable, good for SWC; has the ability to regenerate after dry periods and grows almost everywhere.
- Bermuda grass *(Cynodon dactylon;* locally called *romadi)*: Short, very common; grows mostly on soil bunds.
- *Guaguiat*[2]: Strong, good for SWC.

[3] scientific name unidentified

Local name(s):

metrabawi zala (= canal bund, along contour); *nay hamed zala* (= soil bund)

Land use type:

cropland

SWC category:

structural measure (permanent)

Type of degradation:

loss of topsoil, soil moisture problem (primary purpose is not SWC!)

Combinations:

grass strips, mostly growing naturally

Approach:

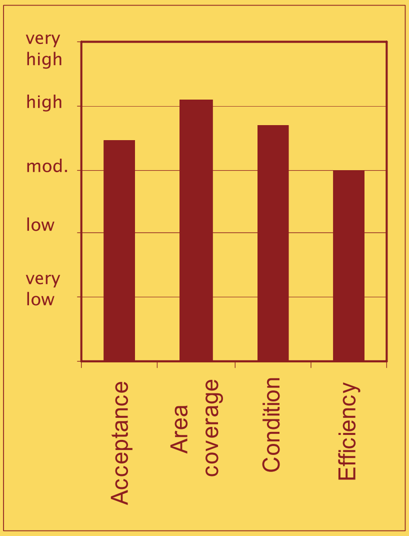
indigenous

References:

Local key informant: No. 42, 67
See Table 45 , page 185/186

Geo-reference: Pt. 8-11
See Table 47, page 195/196

Photos: SLM Eritrea photobase



Acceptance by farmers:

Boundary earth bunds are very common on arable land, which is reflected in the high ranking given to area coverage; in comparison to introduced earth bunds (see page 82) they are well accepted, due to their primary function as 'boundary markers' and the low level of labour linked to this measure. Like stone mulching (see page 79) this measure is not actively implemented, it develops naturally on the small strips which are not ploughed between two fields. Stabilisation through grass cover results in a relatively good condition of boundary earth bunds. This might be one of the reasons why farmers attribute a much higher efficiency to this traditional bund form than to the introduced earth bunds.

2) **Combined stone and earth bunds constructed by farmers** on their own initiative within a field/property serve the purpose of conserving water and soil on the upper part of the field (where water availability and thus productivity are low). These bunds are aligned along the contour. They are replications of SWC measures introduced through campaigns (see "Stone and earth bunds"). They are usually permanent structures, although some farmers move them from time to time (see "Mobile bunds").

Maintenance / modifications

Maintenance activities include the repair of breaches and gaps caused by paths crossing the structures, and of damage from passing animals and tractors. Earth bunds require frequent maintenance, although less than introduced earth bunds (see "Benefits / strengths").

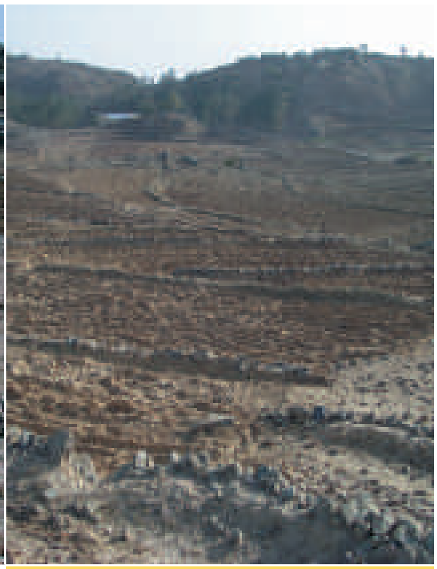
Modification: Earth bunds are sometimes enhanced and reinforced with stones to make them more durable and improve the water conservation effect. Water conservation is a crucial factor for crop production, and this measure helps avoid loss of water to (downstream) neighbouring fields. Local earth bunds are often corrected during campaigns to ensure their alignment along the contour.

Benefits / strengths

- Moisture conservation
- Increased fertility: accumulation of soil, applied fertilisers are not washed out
- Durability: in comparison to introduced earth bunds (see " Stone and earth bunds"), these local earth bunds are usually more compact and stable because of the grass cover and because they are not loosened by ploughing
- Grass cover provides fodder for livestock

Problems / drawbacks

- Drainage in case of heavy runoff: lateral flow of water (if not constructed along the contour), risk of concentration at lowest point and breaching of bund during high-intensity rainfall events
- Waterlogging (in flat, fertile areas, i.e. on *shiebet*)
- Interruption or opening of bunds by paths crossing them creates starting points for rill and gully erosion
- Boundary earth bunds around small plots complicate land management
- Earth bunds are not durable unless they are reinforced with stones or grass



Mobile bunds

Semi-permanent soil embankments; periodical dislocation of bunds or sections of bunds within a farmer's field; distribution and incorporation into the field of the accumulated fertile soil, which has not been ploughed for years.

Purpose / effects

To increase soil fertility through incorporation of the soil accumulated behind a bund, and the earth bund itself, into the field; this soil has not been ploughed for a long time and is therefore fertile.

Description / establishment

Mobile bunds are treated as a separate measure in the present study and not as a modification of introduced contour bunds, since the layout and particularly the purpose of the two measures are completely different.

Permanent and continuous contour bunds serve the main purpose of reducing erosion processes and enhancing moisture conservation by reducing slope length and slope angle, whereas the main objective of periodically dislocated bunds is to increase soil fertility. The approach differs as well: The former are implemented through externally-initiated campaigns, involving technical assistance and a standard layout, while mobile bunds are designed according to individual farmers' criteria. Mobile bunds are implemented in the following steps: 1) Dismantle an existing bund, removing the stones (will be used to build a new bund); 2) Excavate and distribute the accumulated soil behind the bund and the earth bund itself (which has not been ploughed for years), using a hoe; 3) Incorporate this fertile soil into the field through ploughing; 4) Establish a new bund (this is often done directly below the former bund), using only stones, since soil is too precious (fertile); 5) During ploughing, the soil will be automatically moved towards the stone bund.

An option is to use the stones from the dismantled bund to increase an existing bund (that is silted up). Due to partial dislocation, these bunds are no longer continuous. Bunds are mostly moved in the first year after fallow (*tsig'e*). This practice is officially not tolerated on land that has undergone collective treatment during campaigns.

Left: *'Moving bunds' are, first of all, a measure for fertility management: by dismantling stone and earth bunds and re-establishing them in a different place, the accumulated fertile soil can be incorporated into the field.*

Right: *In addition, opening contour bunds helps avoid waterlogging in flat areas and divert the water to drier areas (see water diversion system).*

Local name(s):
mkyar zala, mg'az zala

Land use type:
cropland

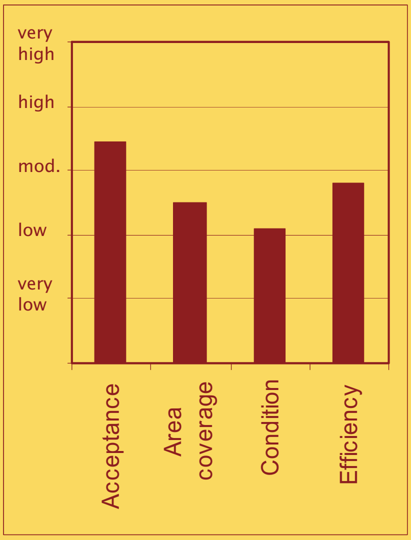
SWC category:
structural measure (semi-permanent)

Type of degradation:
soil fertility decline

Combinations:
water diversion and drainage system

Approach:
indigenous; includes modification of introduced SWC measures

References:
Local key informant: No. 1, 27, 29, 30, 57, 80
See Table 45 , page 185/186
Geo-reference: Pt. 12-15
See Table 47, page 195/196
Photos: SLM Eritrea photobase



Acceptance by farmers:

The acceptance of mobile bunds among farmers ranges between moderate and good. There are some individuals in the study area who implement the measure and recommend its benefits. However, its importance in the study area is rather low, since it is not tolerated on land that has been treated during campaigns.

Maintenance / modifications

Being a semi-permanent structure, mobile bunds are dismantled and re-established every few years (see "Description / establishment"). Maintenance includes repairing gaps after the rainy season.

Benefits / strengths

- Increased yields due to incorporation of fertile soil from the former bund into the field
- Reduced waterlogging effect due to interruption of bunds

Problems / drawbacks

- Mobile bunds are not allowed on collectively conserved land; structures implemented by MoA campaigns are not to be dismantled

Left: Diversion of water within the field in order to balance water availability between dry and moist areas. A bund is opened to release the runoff, which is then diverted through furrows.

Right: Roadside water harvesting through small diversion bunds that direct the water to the cropping area.

Water diversion and drainage systems (I)

A system of various physical elements – often seasonal or semi-permanent, sometimes permanent – including roadside water harvesting structures, diversion bunds (bent and / or graded), diversion / drainage channels, and excess water spillways for water harvesting and runoff management.

Purpose / effects

Site-specific regulation and uniform distribution of available rainwater (runoff) within a farmer's field by:

- harvesting and diverting water to areas where water availability is low, especially during the small rainy season;
- draining excess water from fields where water availability is too high and waterlogging occurs;
- reducing runoff speed to encourage infiltration and reduce soil erosion on sloping land.

Description / establishment

Through local innovation and experimentation farmers have developed sophisticated systems to regulate water availability and drainage. Most agricultural fields are characterised by an uneven distribution of rainwater, which concentrates in the lower part of inclined fields or in natural waterways / valleys (at the bottom of concave land forms). Areas where water availability is high are locally called *shiebet*. Farmers try to retain on-flowing water in the upper part of an inclined field, or, in case of a valley, to divert it to the lateral sloping parts, since these areas – locally called *rekik* – naturally receive less water due to their topographic position. This way, farmers try to achieve an even distribution of the available rainwater on their fields, avoid waterlogging on *shiebet* areas and increase water availability on *rekik* areas.

The design of these water diversion and drainage systems varies from farmer to farmer. They mainly consist of the following elements.

Runoff water harvesting structures, inlets *(me'eley wuhj)*: Short, graded stone (and earth) bunds intended to divert water from roadsides / footpaths / waterways to the field. This is a pure water harvesting structure, mostly seasonal; it is often combined with inlets

Local name(s):

me'eley wuhj (water/river diversion); *me'eley metreb* / *mkf'fal*, *me'eley zala* (diversion ditch); *megedi may* (waterway);

mesengele tiel[1], *kurbata* (bent diversion bund);

metenfesi (outlet), maffa (hidden outlet)

Land use type:

cropland; water harvesting areas include roads, pathways, settlement areas, etc.

SWC category:

structural measure (semi-permanent / seasonal)

Type of degradation:

soil moisture problem (dry conditions), waterlogging

Combinations:

stone and earth bunds, terraces, deep furrows

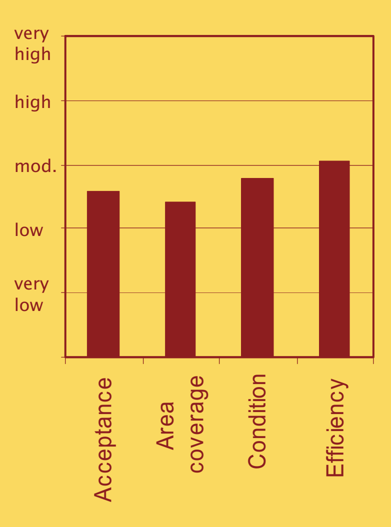
Approach:

indigenous; with introduced elements

Refernces:

see page 61

[1] The literal translation of mesengele tiel is "rib of goat." This name is confusing since it is not understood by all farmers and is also used to refer to a certain specific landform.



Acceptance by farmers:

The area coverage and the importance of the measures is moderate to low. It is often applied in specific areas, e.g. along natural waterways and along roads or footpaths. Several farmers have elaborated sophisticated systems through years of experimenting, but these are exceptions. Fragmented land distribution does not encourage these systems. Drainage of excess water to neighbouring fields will inevitably lead to conflict between the field owners, so in practice these local systems are only applicable within a farmer's own field. Given the distribution of fragmented small plots to different owners, this is rarely possible. Acceptance of these drainage systems by farmers is thus only low to moderate.

The condition of water diversion and drainage structures is perceived as moderate, one of the reasons being the difficulty of providing the continuous supervision and improvement which is needed to keep a system fully functional.

(openings in boundary bunds); the dimensions of the bunds are often smaller than those of diversion bunds, sometimes they consist of a simple line of stones. Water harvesting is important to make maximum use of the unreliable small rainy season.

Graded stone / earth diversion bunds within fields (*me'eley wuhj*): Semi-permanent / permanent graded bunds for runoff management, intended to divert, distribute and simultaneously slow down runoff within a field. Rainwater is distributed evenly, also to areas where availability is low; infiltration is enhanced and surface erosion is reduced. Made of stones and earth. Width: approx. 20-40 cm; length: only 1-5 m. The gradient of the bunds regulates runoff speed and is usually low, thus enhancing infiltration and ensuring in-situ moisture conservation where needed. Farmers find the best layout and gradient by trial and error. Diversion bunds are originally constructed with stones only; soil is added later on while ploughing. Combined stone and earth bunds are much more efficient with regard to runoff diversion (stone bunds let a substantial amount of water pass, which can also be an intended effect, see below).

Contour stone bunds are used in these systems as a kind of semi-permeable barriers to regulate runoff and water availability: they retard runoff and thus enhance infiltration, increasing soil moisture on the upper, more inclined part of the field where water availability is low; at the same time, a substantial part of the runoff passes the stone bund and provides enough water for the lower part of the field where water availability is naturally higher.

Bent / curved diversion bund (*mesengele tiel*, *kurbata*): Semi-permanent / permanent stone and earth bund in a curved design, intended to slow down and divide runoff in areas where it tends to concentrate due to topography (e.g. natural waterways, valley bottoms) and safely divert it laterally to (foot)slopes. The bent shape ensures high stability and reduces concentrated runoff with high erosive energy. Additional vegetative measures, such as a grass strip on the bund, are used to further stabilise the structure. This type of diversion bund is applied specifically to protect 'hot spots' such as broken terraces, gully heads and areas affected by pipe erosion from further degradation (see also "Gully / pipe reclamation"), as well as to support existing check dams. Moreover, it serves to distribute water uniformly to fields situated along the sides of a natural drainage system.

Diversion and drainage ditches: Semi-permanent or seasonal small ditches, often in combination with bunds, but also implemented as an independent measure. They are constructed using a hoe. Diversion ditches distribute and divert water within a field. They are mainly used in flat areas to drain water out of areas affected by waterlogging and divert it to *rekik* land; they can also take the form of cut-off drains at the top of the affected field. Cutting the natural drainage lines, they intercept runoff from small and medium rainfall events, reduce its speed, and enhance in-situ water conservation, thus reducing the risk of damage and siltation on the main bund. The dimensions vary according to the amount and speed of runoff in the drainage system.

Deep ploughed furrows are small canals dug by oxen plough for the purpose of diverting and draining water on a field. In their function and purpose they are similar to diversion ditches, and they can also be an integrated part of a water diversion and drainage system; however, since they are a seasonal agronomic measure, they are described below in the section on the "Local ploughing system."

__Left__: A solid diversion bund protects a field which frequently used to be affected by high runoff due to its location in a natural drainage line.

__Right__: Capturing runoff from the road and diverting it to cultivated fields by a graded stone and earth bund (in this case: affected by passing cars).

Water diversion and drainage systems (II)

(Continuation from page 60)

Outlets: Semi-permanent / seasonal outlets in existing contour bunds, constructed mostly in flat areas to drain excess water to the neighbouring field further downstream and to avoid waterlogging. When applied to a series of subsequent terraces or bunds, outlets are laid out in a zigzag manner. There are two types of spillways: 1) Open outlets (*metenfesi*) are cut through the top ridge of the bund / terrace; in seasons of low rainfall these openings are closed in order to take advantage of the limited water available. 2) Hidden outlets (*mafa*) penetrate the bund / terrace in the form of a pipe; the opening is filled with stones and branches in order to retain soil, manure and organic residues while letting the water pass.

Maintenance / modifications

This type of diversion and drainage systems require continuous super-vision by the farmer. The layout of the bunds (e.g. gradient) need to be modified or improved according to the effects observed. In the event of heavy rainfall, inlets and spillways need to be closed to protect the own and the neighbouring field from excess water; later on they need to be reopened.

Benefits / strengths

- Maximum use of limited water; high impact on water availability and thus productivity (particularly important in dry periods and on fields where water availability is naturally low)
- Runoff retardation, minimisation of surface erosion through runoff
- Controlled drainage, minimisation of damage caused through concentrated runoff (gullies)
- Protection of existing structures (terraces, bunds along contour, check dams)

Problems / drawbacks

- Conflicts between owners of neighbouring fields due to drainage of excess water through (partly hidden) spillways and drainage ditches, especially on fields that are prone to waterlogging
- Human-induced gully erosion due to spillway construction

Refernces:

Local key informant: No. 1, 2, 27, 37, 42, 57, 72, 80, 83
See Table 45 , page 185/186

Geo-reference: Pt. 16-27
See Table 47, page 195/196

Photos: SLM Eritrea photobase

Gully / pipe reclamation

Restoration of areas affected by gullies, collapsed terraces and pipe erosion using a set of structural measures including check dam construction, earth filling and diversion bunds to protect the site from run-on.

Purpose / effects

Prevention of further expansion of eroded or collapsed sections and subsequent damage on fields downstream; re-establishment of a sound, level terrace to recover lost cropping area, facilitate land management practices, and conserve soil and water (which in case of pipe erosion is directly and rapidly drained to the next-lower field).

Description / establishment

This technology is designed for reclaiming terraces affected by specific types of advanced pipe or tunnel erosion, breaching (collapse of terrace sections), or beginning gully erosion. Establishment is according to the following steps:

1) Build a bent stone and earth bund (in shape of half-moon) to protect the affected (subsided / collapsed) part from further run-on by diverting the water laterally in two directions. This step is especially important in cases where the collapsed section of the terraces or gullies are too big to be levelled up to the terrace bank (see following steps). Dimensions of the bund are variable. 2) Let grass develop to stabilise the bund itself as well as the area between the bund and the affected part of the terrace (no ploughing activities on this strip of land). 3) Dig out the soil between the subsided section (in case of pipe erosion) and the outlet (usually in the lower part of the terrace riser) to uncover the eroded pipe. 4) Construct a stable stone wall (see "Stone check dams") with a good foundation to close the breach in the terrace riser. 5) Fill the hole / gully behind the stone wall up to the level of the terrace, either using the previously excavated soil (in case of pipe erosion) or soil from other areas, or simply letting the soil accumulate behind the check dam during the rainy season; compact the soil. 6) In case of successful restoration: Remove the bent earth bund established in step 1 (see above) to encourage further siltation until the affected section is level with the field.

Left: *A nicely rehabilitated terrace that has been seriously affected by pipe erosion. The bent bund in the back diverts oncoming water to both sides and protects the affected part of the terrace.*

Right: *Filling a collapsed terrace part – caused by pipe erosion or initial gully development – with stones alone might not sufficiently prevent further erosion processes.*

Local name(s):
hgag mmla'e (*krar* / *gudguad mmla'e*)

Land use type:
cropland

SWC category:
structural measure (permanent)

Type of degradation:
gully/pipe erosion,
collapsed/breached terraces

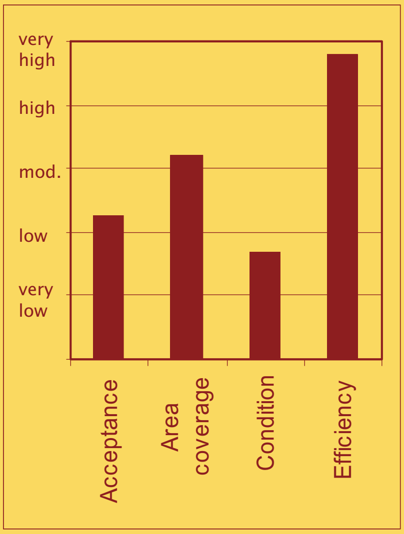
Combinations:
water diversion

Approach:
indigenous; experimentation; replication of some previously introduced measures

References:
Local key informant: No. 1, 2, 3, 16, 21, 33, 67
See Table 45 , page 185/186

Geo-reference: Pt. 29-32
See Table 47, page 195/196

Photos: SLM Eritrea photobase



Acceptance by farmers:

This technology has been successfully tested and implemented by several individuals who are very active in SWC, to protect specific areas such as degradation "hot spots." Although it has proved to be very effective in reclaiming damaged land and avoiding downstream damage, and although the problem of pipe / gully erosion and collapsed terraces is quite common, this technology is not widespread. One of the main reasons for this is the high labour input which is required for establishing the measure.
Apart from a few good examples, gully and pipe reclamation measures are mostly in poor condition. General acceptance among farmers in the catchment is low.

Farmers also tried to solve the problem of pipe erosion by simply filling the subsided section or the pipe with stones, earth, and other material. This method often fails to be effective since subsurface erosion tends to continue despite the filling. If this method is applied, it should definitely be supported by additional measures such as a protective bund upstream (see step 1 above).

Another option is to simply build a strong check dam with a solid foundation, plugging the gaps between the stones with earth on its upper side, e.g. by adding clods during ploughing. Fertile soil then accumulates gradually behind the check dam, and cultivation can start even before the affected section becomes level with the rest of the field.

Maintenance / modifications

Aside from the high initial labour input for establishing the structure, this technology, if well-applied, requires few maintenance activities. These include occasional monitoring, especially after heavy rains, and repair of possible damages. In cases involving only a check dam, the structure requires regular maintenance, and the stone wall needs to be increased each year to keep up with siltation.

Benefits / strengths

- Enables to recover lost cropping area within a short time (rehabilitation takes a few days up to 4 years, depending on the magnitude of the gully)
- Prevents further expansion of the damaged area
- Facilitates land management on the terrace (e.g. ploughing) considerably
- Conserves water, increases water availability
- Accumulation of soil
- Avoids downstream damage from concentrated runoff
- Avoids waterlogging (water is diverted laterally)

Problems / drawbacks

- High initial labour input, hard work
- Requires availability of large stones
- Requires technical knowledge (for construction of check dam with good foundation)

Above: Rows of sisal keep animals from entering cropland or settlement areas. Once well adopted, live fences have now become very rare in the study area.

Live fences

Rows of plants along roadsides or boundaries of settlement area (in the study area, sisal is the most frequently used plant for live fences).

Purpose / effects

The main purpose of sisal fences is to keep animals away from cropland. However, they also conserve the soil and stabilise the land in areas where floods occur during rainy seasons.

Description / establishment

Sisal is planted in rows along roadsides or on borders of settlement areas. The plants are closely spaced. Planting is mostly done during the rainy season in order to achieve good growth. This practice was originally introduced by Italian colonisers. Farmers nowadays consider it a local measure since it has been applied for generations.

Maintenance / modifications

Replacement of dried-up plants

Local name(s):

nay agrab mesmer, *nay e'ka mesmer* (= sisal), *hiwetawyan hatsur*

Land use type:

settlement area / roads, cropland

SWC category:

vegetative measure

Type of degradation:

loss of topsoil, animal trampling

Combinations:

none

Approach:

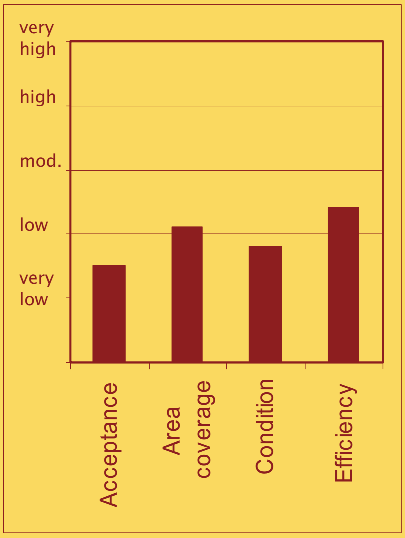
indigenous (introduced several decades ago, during Italian colonisation)

References:

Local key informant: No. 41, 83
See Table 45 , page 185/186

Geo-reference: Pt. 33, 34
See Table 47, page 195/196

Photos: SLM Eritrea photobase



Acceptance by farmers:

This measure has become very rare, with only few Sisal fences left mainly in Adi Jin. Most of them are in a poor condition, i.e. have lots of gaps. According to farmers' statements the plants have died due to long drought periods – although sisal is relatively drought resistant – and due to lack of maintenance. Acceptance is low to very low.

Benefits / strengths

- Protects cropland from animal grazing, especially near roads or settlement area (main purpose)
- Controls soil erosion, slows down heavy runoff
- Stabilises the land (roots)
- Sisal is drought-resistant

Problems / drawbacks

- Requires maintenance (e.g. filling gaps)
- Access to new seedlings is difficult. However, experts disprove this opinion, since suckers and bulbils can easily be multiplied.

Above: Overview of the Ametere enclosure (Adi Jin): Enclosures help regenerate vegetation cover and provide multiple benefits to the community, including the generation of income (by selling trees and grass).

Permanent area enclosure; natural regeneration of vegetation

Permanent area enclosure with the aim of conserving the vegetative cover or letting the vegetation regenerate naturally.

Purpose / effects

Closures in Adi Jin and Quandoba preserve the natural vegetation and provide a source of wood for different purposes, e.g. for house construction or income generation (community benefit), whereas in Afdeyu the area closure protects a sacred place.

Description / establishment

The Ametere area (46 ha) in Adi Jin has been closed for approx. 80 years, thus preserving a dense forest with a high variety of local shrubs and trees. Some foreign species have been introduced (see table below). The area belongs to the community. Within a small area, each community member individually owns about six eucalyptus trees, coupled with the responsibility to care for them and the right to use them according to his or her needs. The use of the natural resources within the enclosure is clearly regulated (see below). The area is not fenced off; 14 farmers take turns at guarding the enclosure; they are paid 45–50 kg of grain/person/year by the community. The enclosure in Quandoba (12 ha, existing since about 100 years ago) has similar natural and management characteristics. The enclosure in Afdeyu is different, both with regard to its purpose – it protects a sacred forest – and in size (it covers only a very small area).

Maintenance / modifications

Regulations set up by the village control the use and management of natural resources in the Adi Jin enclosure. Collecting of wood (dry branches) is restricted to certain purposes or situations:

- fuelwood for burial ceremonies (families in mourning);
- fuelwood for carrying out certain local professions (e.g. local blacksmiths);
- wood for ploughing implements (all community members);
- wood for coal-making for incense (Church).

Local name(s):
hiza'eti

Land use type:
mixed land (crops, pastures, trees)

SWC category:
management measure

Type of degradation:
forest overuse, vegetation degradation

Combinations:
cut-and-carry (grass)

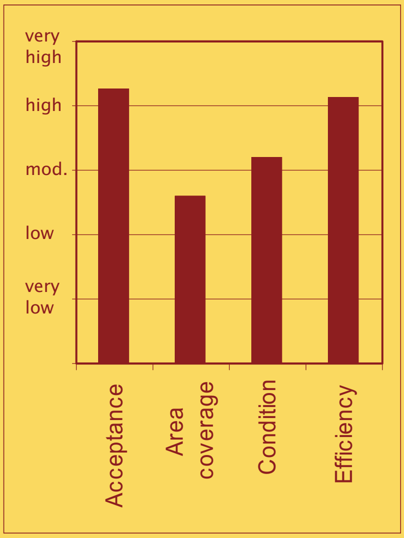
Approach:
indigenous

References:

Local key informant: 25, 65, 67
See Table 45 , page 185/186

Geo-reference: Pt. 35–37
See Table 47, page 195/196

Photos: SLM Eritrea photobase



Acceptance by farmers:

Each village has a protected area where woody vegetation has been traditionally preserved over generations. Area coverage is high in Adi Jin, moderate in Quandoba and very small in Afdeyu. Generally, area coverage is low compared to the total village area. The enclosures are well-accepted within the communities.

In Adi Jin, grazing is permitted once every year for oxen, from May to the beginning of August. Within the enclosure there is a small area of fertile cropland, which has been hired for 10 years.

Income earned by selling crops, grass and wood from the enclosure is saved in the bank for matters of public interest or of communal benefit, such as public infrastructure development (electricity, water supply), church development, and the establishment or maintenance of other village facilities.

Benefits / strengths

- Direct economic benefit: income from selling wood and grass generates "communal capital" that can be accessed whenever needed
- Source of fodder
- Source of wood for construction

Problems / drawbacks

- No problems reported

Table 13: Plant species identified in the Ametere enclosure in Adi Jin:

Native trees / shrubs (local name in brackets):

- *Acacia abyssinica (che'a fentera)*
- *Acacia etbaica (seraw)*
- *Acokanthera schimperi (mebet'e)*
- *Calpurnia aurea (hatsawts)*
- *Clerodendron myricoides (sur betri)*
- *Carissa edulis (agam)*
- *Croton macrostachyus (tambuk)*
- *Dodonaea angustifolia / dodonaea viscosa (tahses)*
- *Eteganotaenia Araliacea (endr guhila)*
- *Euclea schimperia (kiliaw)*
- *Euphorbia abyssinica (kolkual)*
- *Ficus carica (beles 'fiki')*
- *Hyparrhenia spp. (saeri)*
- *Juniperus procera (tsihdi)*
- *Maytenus senegalensis (argudi)*
- *Maytenus arbutifolia (atat)*
- *Meriandra bengalensis (nihba)*
- *Myrica salicifolia (niibi)*
- *Myrtus spp. (tsetso)*
- *Olea africana (awlie)*
- *Otostegia integrifolia (chindog)*
- *Rhamnus staddo (tsedo)*
- *Rhus abyssinica (amus)*
- *Rosa abyssinica (kolodeshum)*
- *Rumex usambarensis (hihot)*
- *amatere*[1]
- *geretsag'e*[1]

Native grass species:

- *meker*[1]
- *Cynodon dactylon (romadi)*

Introduced plant species

- *Eucalyptus spp. (kelamitos)*

Animal species

- Jackal (*wekaria*)
- Hare (*mantile*)
- Birds (various species: *kokah, zagra, srnih*)

Additional plant species found in Afdeyu enclosure

- *Aloe spp. (ere)*
- *Buddleja polystachya (metere)*
- *Phytolacca dodecandra (shibti)*
- *Pterolobium stellatum (konteftete)*
- *Dabza*[1]
- *Solanum nigrum (Htsawts)*

[1] local name (botanical name not known)

Source of botanical names: Estifanos Bein, et al 1996

Left: Dry barley (in the background), green barley (second sowing within the same season) and potatoes: crops are rotated to maintain the yields.

Right: Maize, here together with onions, is often planted in the first cropping season after fallowing to make use of the replenished soil fertility.

Crop rotation

Cultivation of different crops in recurring succession during three consecutive years, followed by a year of fallow, on a given field.

Purpose / effects

The main purpose of crop rotation and fallowing is to maintain or even increase yields. Farmers do not consider this practice a part of soil and water conservation activities, even though they are aware of the fact that it plays an important role in the maintenance and restoration of soil fertility. Another important purpose of crop rotation is linked to the limited availability of grazing land in Afdeyu: the fallow period provides an opportunity for animal grazing without affecting crops.

Description / establishment

Crop rotation and fallowing are integrated elements of the local farming system and have been practised for generations. In the study area, a 4-year crop rotation cycle includes the following periods (with typical crop sequence):

Figure 3: *Typical crop rotation cycle*

Year	1st year	2nd year	3rd year	4th year
Name of period	*tsig'e*	*kerim*	*salsien*	*tsig'e*
Main crop	barley	wheat	*hanfets*[1]	fallow[2]

[1] *hanfets:* mixed cropping of barley and wheat
[2] fallow (temporary enclosure, grazing towards the end of the season)

This crop sequence can vary depending on farmers' individual needs and preferences and on the fertility status of the field in question. Other crops commonly planted in the area include: maize, *teff (Eragrostis teff)*, and finger millet (predominantly grown during small rainy season); potato, chickpea, linseed, lentils and beans (during main rainy season). Furthermore, intercropping is traditionally practised as well (see "Intercropping / mixed cropping" (page 75) Table 14 indicates crops cultivated and field activities carried out in the different cropping seasons. For a calendar of agricultural activities during one 4-year cropping cycle see Table 5 on page 29.

Local name(s):
mlw'wat zeri'e / mkyyar zeri'e

Land use type:
cropland

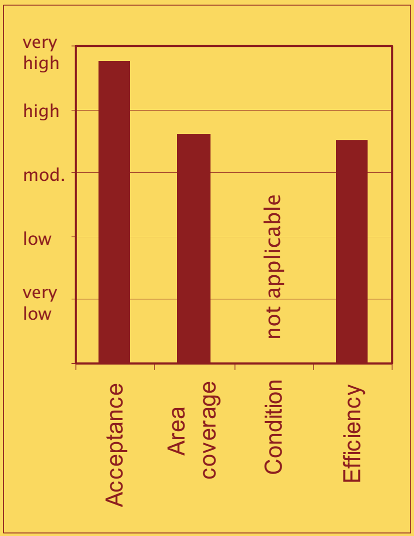
SWC category:
agronomic measure

Type of degradation:
soil fertility decline

Combinations:
fallowing, rotational grazing

Approach:
Indigenous

References:
Local key informant: No. 67
See Table 45 , page 185/186
Geo-reference: n/a
See Table 47, page 195/196
Photos: SLM Eritrea photobase



Acceptance by farmers:

Crop rotation is a wiedespread traditional measure that is regulated at the village level and is highly accepted in the area.

Fertility management practices (especially manuring) and construction / maintenance of SWC measures are mainly carried out at the beginning of the *tsig'e* period, in the first year after fallow period. This is due to different reasons:

1. Farmers want to make maximum use of their land's replenished nutrient status after the fallow period. The expectation of higher yields and thus a more favourable cost-benefit ratio animates them to make greater investments.
2. Farmers apply manure mainly during *tsig'e*, based on the assumption that its impact on soil fertility and crop production will last for the next three years (long-term strategy).
3. Since the land has been used for grazing towards the end of the preceding fallow period, many SWC measures – particularly physical measures – are damaged and need to be repaired.
4. Land use rights are not secure in the long term. Timing of fertility management and SWC activities thus also depends on land distribution cycles, which normally last 7 years. Farmers prefer to concentrate their limited labour and time in the beginning of a land distribution cycle in order to best benefit from the investments made during their ownership of the land. Towards the end of the cycle these activities gradually decrease. Consequently, after the land redistribution soils are leached and low in fertility, again forcing the new field owners to invest in fertility management and SWC.

Maintenance / modifications

Annual and seasonal practice

Benefits / strengths:

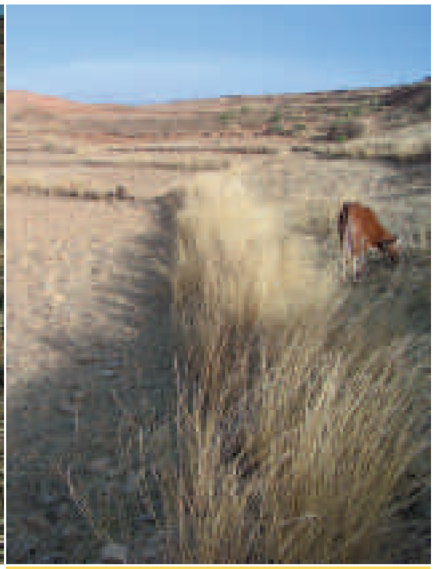
- Diversification of crops minimises the risk of crop failure
- Prevents one-sided nutrient uptake and decreasing yields
- Minimises pest, insect and weed infestation
- Provides a variety of different products

Problems / drawbacks:

- There are no problems directly related to crop rotation. However, farmers mentioned the unavailability of improved seeds / varieties (e.g. potato) to boost crop production.

***Table 14**: Cultivated crops and field activities in the different cropping seasons*

	Tsig'e (2 years)		***Kerim***	***Salsien***
	Fallow period *(tsig'e hamed)*	**1st crop cycle**	**2nd crop cycle**	**3rd crop cycle**
Cultivated crops	No crop cultivation: temporary enclosure (January–mid May), grazing (mid May – August) (see "Fallowing")	crops requiring a relatively high fertility status, e.g. barley, maize, potatoes, beans	crops that are less demanding with regard to soil fertility, e.g. wheat, linseed, lentils	mostly mixed cropping: mainly wheat and barley; also wheat, linseed, lentils
Tillage practices (see "Local ploughing system")	most traditional ploughing practices for land preparation: *sito*, *aimi*, *teslas*, *mgunbat*, *mimgab*, *mirwah*;	Sowing, Weeding	reduced ploughing activities, i.e. only *nekli* and sowing; *mirwah* (weed control) where necessary	reduced ploughing activities, i.e. only *nekli* and sowing; *mirwah* (weed control) where necessary
Soil fertility management	high input, especially manuring	done during fallow period	reduced input	minimised input; some farmers apply chemical fertiliser
Maintenance / construction of SWC structures	major maintenance / repair work and construction of structural measures	minor maintenance work	minor maintenance work as integrated part of farming activities	minor maintenance work as integrated part of farming activities



Left: every four years one village zone is left fallow to regenerate soil fertiliy and organic matter.

Right: after a strict closure of about 5 months, the fallowed fields are opened for grazing (from May to August). Then the preparation for the first cropping season begins with a series of ploughing activities (see local ploughing system).

Fallowing

Periodical regeneration phase applied on cropland, comprising three stages: 1) total closure; 2) open for grazing, but no agricultural activities; 3) land preparation for next cropping season.

Purpose / effects

The main purpose of fallowing is to restore soil fertility by letting the soil rest during one year (no cultivation of crops). Farmers do not consider it a part of soil and water conservation (in the narrower sense of the term). Another important purpose of fallowing is to enable grazing (after temporal closure), since permanent grazing land in Afdeyu is very limited.

Description / establishment

Fallowing is an integrated part of the local crop rotation system (see Calendar of agricultural activities, page 29). After three consecutive years of cultivation the land is temporarily closed for regeneration. In the first four to five months after the harvest of the last cropping season, i.e. from December / January to April / May, the land is closed for all types of land use activities: grazing, cut-and-carry of grasses and wood collecting are prohibited. From mid May to August, the closed area is opened for grazing – first for oxen only, later for all animals. Finally, in September, ploughing activities are taken up to prepare the land for the coming cropping period. In farmers' perception, the fallow period lasts until June or July of the following year, when land preparation ends and new crops are sown, and includes maintenance of SWC measures, application of manure (see "Compost / manure application") and different types of ploughing (see "Local ploughing system"). Closed areas and grazing are controlled by a watchman.

The fallow period is locally called *tsig'e,* just like the first year of cropping – which can be confusing for outsiders – or also *tsig'e hamed*. Rotation cycles, and thus fallow periods, are relayed in the four village zones: each year, the fallow rotates from one zone to the next (see Table 15, page 72). The only zone that is excluded from fallowing is Gedena, the intensively used land around the settlement. Here, treatment with well-maintained SWC structures and frequent manuring enable continuous cropping without intermittent fallow periods.

Local name(s):

tsig'e / tsig'e hamed; *hiza'eti* (= closure); *kadra* (= fallow); *Kadra* is the official term for fallow. Farmers use it to refer to fields that are not under cultivation (= no ploughing or planting), but open for animal grazing. By contrast, *hiza'eti* is an area temporarily or permanently closed for grazing.

Land use type:

cropland

SWC category:

agronomic/management measure

Type of degradation:

soil fertility decline

Combinations:

crop rotation, rotational grazing

Approach:

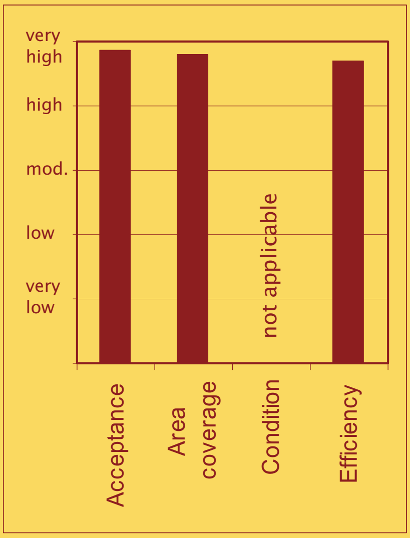
indigenous

References:

Local key informant: No. 25, 65, 67
See Table 45 , page 185/186

Geo-reference: n/a
See Table 47, page 195/196

Photos: SLM Eritrea photobase



Acceptance by farmers:

Fallowing is a traditional measure that is regulated at the village-level and is therefore practiced by all farmers and in all zones except the Gedena zone, which is intensively used and thus well-conserved (frequent manuring and maintenance of SWC measures). Both area coverage and acceptance of fallowing are very high.

Grazing is linked to the fallowed areas only during the period from May to August. After the crop harvest, animals are left to graze freely (uncontrolled grazing) or are brought to areas outside the study area (e.g. the eastern escarpment).

Maintenance / modifications

Annual / seasonal practice.

Benefits / strengths

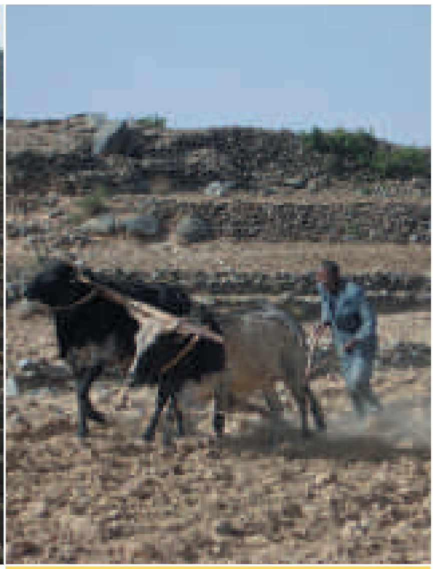
- Allows the land to rest and regenerate
- Allows grazing on cropland (annual rotation)

Problems / drawbacks

- Due to shortage of fodder and grazing land, the cropping areas are grazed after harvesting , leaving no crop residues to protect the soil and counter the loss of organic matter

***Table 15:** Pattern of crop rotation and fallowing within four village zones*

	Zone A: Grat Hamushte	**Zone B: Kelkel**	**Zone C: Sinihabera**	**Zone D: Aguari'e**
Year 1	1st year of crop cycle (*tsig'e*)	2nd year of crop cycle (*kerim*)	3rd year of crop cycle (*salsien*)	Fallow
Year 2	2nd year of crop cycle (*kerim*)	3rd year of crop cycle (*salsien*)	Fallow	1st year of crop cycle (*tsig'e*)
Year 3	3rd year of crop cycle (*salsien*)	Fallow	1st year of crop cycle (*tsig'e*)	2nd year of crop cycle (*kerim*)
Year 4	Fallow	1st year of crop cycle (*tsig'e*)	2nd year of crop cycle (*kerim*)	3rd year of crop cycle (*salsien*)



__Left__: Ploughing science: In the first year after fallow the local ploughing system includes up to 7 runs in different directions, each with its specific purpose.

__Right__: Nearly all land users continue to use the mahresha, the traditional ox-drawn plough, to cultivate their fields. While the mahresha is well-adapted to the fragmented plots and the structural measures applied, ploughing by tractor is problematic due to lack of access and small field sizes..

Local ploughing system

Land preparation between two crop cycles; involves ploughing in different directions – at an angle to the slope and along the contour lines – in a series of consecutive steps, using an oxen plough; includes deep furrows.

Purpose / effects

Farmers do not perceive SWC as a major purpose of ploughing. They list the following reasons for this measure:

1. Preparation of a suitable seedbed for crops (to facilitate germination)
2. Reduction of runoff, erosion, washing out of seed and fertiliser
3. Weed control
4. Incorporation of organic residues and compost / manure into the soil
5. Improvement of runoff infiltration and conservation of soil moisture
6. Water harvesting (diversion of water to fields)
7. Distribution of water within fields
8. Improvement of soil aeration
9. Breaking of hard pans and loosening of clods and compacted soil (caused by animal trampling and fallowing)
10. Division of field into sections for easier sowing (i.e. to avoid sowing same section twice)

Description / establishment

Farmers are aware of the crucial impact that tillage practices have on runoff, infiltration and subsequent evaporation, and thus on soil moisture content and soil erosion. Over generations they have developed a tillage system consisting of a series of subsequent ploughing activities. The following table provides an overview of the sequence and characteristics of these ploughing activities. Farmers plough their fields up to seven times during *tsig'e*. However, in practice this is rarely the case. The number of ploughing activities carried out depends on each farmer's capacities. In Gedena zone farmers practise the ploughing system generally applied in *salsien* and *kerim* seasons, since Gedena land is not fallowed.
Fields are ploughed by oxen, using a local implement called *mahresha*. Furrows reach a depth of 10-20 cm, depending on soil workability, oxen strength, slope angle, soil depth, and the purpose of ploughing. The term *neghi* refers to a single plough line of variable depth, created in one pass. Deep *neghi*, i.e. **deep furrows**, are applied for different purposes:

Local name(s):
gdme gdmi mhras or *kinatawi mhras* (= contour ploughing); *neghi* (furrows)

Land use type:
cropland

SWC category:
agronomic measure

Type of degradation:
surface erosion, gully erosion

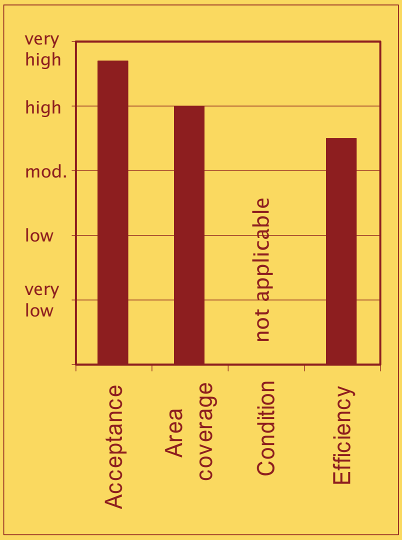
Combinations:
all types of SWC measures

Approach:
indigenous; has been applied for generations

References:
Local key informant: No. 25, 65, 67
See Table 45 , page 185/186

Geo-reference: n/a
See Table 47, page 195/196

Photos: SLM Eritrea photobase



Acceptance by farmers:

This ploughing system is a local practice applied by all farmers. Area coverage is therefore high and acceptance among the villagers excellent.

- Water harvesting: deep furrows outside the field trap external runoff and direct it onto the field.
- In situ water conservation / improvement of infiltration capacity through deep ploughing across the entire field, e.g. during the short rainy season.
- Land subdivision: just before sowing farmers use the plough to divide their fields into 2-3 sub-plots *(tilmi)*; this facilitates the process of sowing by hand by reducing the risk of double sowing.

At the same time, deep furrows can serve to drain excess water or trap eroded soil. Spacing between two deep furrows is usually 2-5 m, depending on farmers' preferences, the intended purpose, and the slope angle; on steep land ploughing is deeper and the plough lines are closer together. *Sibet* is the local term for the ploughing depth, which can reach up to 30 cm.

Maintenance / modifications

Annual / seasonal practice.

Benefits / strengths

- Increases infiltration of water and conserves soil moisture
- Regulates water availability (diverts water from moist to dry areas)
- Reduces soil erosion
- Controls weeds
- Improves soil structure and aeration of the soil
- Provides a good seedbed

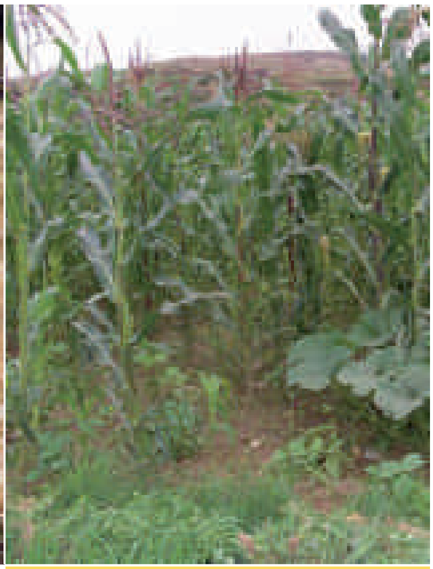
Problems / drawbacks

- Ploughing in dry periods facilitates wind erosion
- Requires high labour input, particularly on stony or steeper areas
- *Duka* soil is hard and difficult to plough during the dry season

Table 16: Types of ploughing

Name meaning	**Timing / season**	**Layout**	**Purpose / function / specific descriptions** (farmers perception)
sito	August / September in *tsig'e*[1]	contour ploughing (wide spacing) / deep furrows	• conservation / harvesting of water (increased infiltration and storage) during summer rains (main rainy season) • breaking of hard pans • takes place after closed areas are reopened for cultivation (after grazing)
aimi	October / November in *tsig'e*[1]	up-and-down / diagonal ploughing (narrow spacing)	• loosening / mixing of soil, aeration • ploughing of areas that have not been ploughed in *sito* • narrow ploughing to minimise evaporation and conserve moisture • up-and-down ploughing is no problem since there is no rain during this time
teslas 'to do it for the 3rd time'	December and January in *tsig'e*[1]	contour ploughing (narrow spacing)	• perpendicular to *aimi* furrows
mimgab 'to feed'	March in *tsig'e*[1]	contour ploughing	• optional • increase of soil moisture content by trapping water and improving percolation
mgunbat 'to do it during May'	May in *tsig'e*[1]	deep furrows / contour ploughing (wide spacing)	• trapping and conservation of water during *akeza* rains (= small rainy season) to facilitate growing of some early-sown crops (e.g. maize) / land preparation for sowing • improvement of soil aeration
nekli	March to May in *kerim*[1] and *salsien*[1]	diagonal / contour ploughing	• first ploughing activity during *kerim* and *salsien* cropping seasons • trapping and conservation of water, softening of the soil, breaking of hard pans, land preparation for sowing
mirwah	June in *tsig'e*[1], sometimes also in *kerim*/*salsien*[1]	turning over the soil	• weed control (after weed growth during small rainy season) • done also in *kerim* and *salsien* if necessary
sowing (local term: *zer'e*)	June / July in *tsig'e*, *kerim* and *salsien*[1]	deep furrows / contour ploughing (narrow spacing)	• seedbed preparation / covering seeds with soil • done carefully along contour to protect soil against erosion • subdivision of the field into various sowing sections *(tilmi)*

[1] See "Crop rotation" for explanation of *tsig'e*, *kerim* and *salsien*



Left: *Wheat and barley are the two crops that are most commonly combined by farmers to reduce the risk of crop failure.*

Right: *Mixed cultivation of faba beans (fajoli) , maize and pumpkin.*

Intercropping / mixed cropping

Mixed cultivation of two annual crops at the same time and on the same field. The most common combination is wheat and barley; a less common combination is maize and beans (legumes).

Purpose / effects

The main purpose of this practice is not SWC, but to minimise the risk of a complete crop failure, maximise yields, and thus increase food security in dry years. Mixed cropping has the positive side-effect of diversifying the diet.

Description / establishment

Mixed cropping of wheat and barley (locally called *hanfets*) forms part of the traditional cropping cycle, especially in 3rd year (*salsien*) of the cycle, when soil fertility has decreased. Farmers mix the seeds (1/3 wheat and 2/3 barley) and then broadcast this mix. The two species are distributed randomly, not by line (no strip cultivation). Barley is early-maturing, which reduces the risk of crop failure. Wheat and barley are harvested at the same time, i.e. farmers wait until the wheat is dry.

Some farmers also mix maize and beans (*fajoli*, *faba*). Intercropping with beans considerably reduces the risk of crop failure, since beans mature earlier than cereals; furthermore, beans have a positive side-effect on soil fertility due to their nitrogen-fixing function.

Maintenance / modifications

Annual / seasonal practice.

Local name(s):
hanfets, miwhrar

Land use type:
cropland

SWC category:
agronomic measure

Type of degradation:
soil fertiliy decline

Combinations:
all types of SWC measures

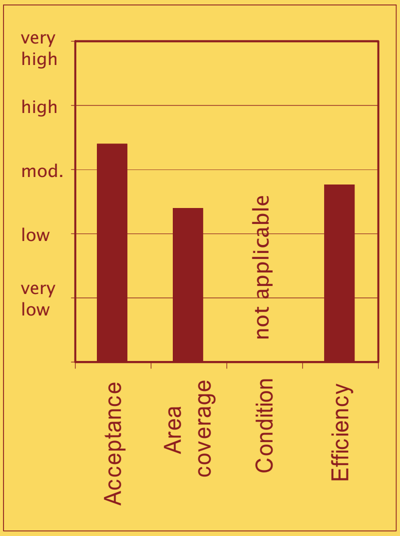
Approach:
indigenous

References:

Local key informant: No. 25, 65, 67
See Table 45 , page 185/186

Geo-reference: n/a
See Table 47, page 195/196

Photos: SLM Eritrea photobase



Acceptance by farmers:

Hanfets – traditional mixed cropping of barley and wheat – is a very common and widespread practice; mixture of maize and beans is less common. However, farmers estimate area coverage to be low to moderate. This may have different reasons: (1) The practice is an integrated part of the farmers' crop rotation system and is therefore not considered a (separate) SWC measure; (2) The practice is only applied once every four years (on a given area). Acceptance is rated moderate to high.

Benefits / strengths

- Minimises risk, increases food security
- Prevents unbalanced use of nutrients
- Nitrogen-fixing function of beans (less known, secondary purpose)

Problems / drawbacks

- Wheat-and-barley mixed cropping: although barley matures earlier than wheat, the two crops are harvested at the same time, which may result in the negative effects of 1) barley drying out and starting to drop its grains (loss of crop yield), and 2) dry barley seeds moulding due to rainfall
- Dominance of soy bean over maize when sown at the same time
- Shortage of soy bean seeds

Left: Animal dung and other organic material is accumulated and mixed in the compost pit, where it decomposes over time.

Right: Heaps of compost on an unploughed plot, ready for incorporation.

Compost / manure application

Biological decomposition of collected organic waste by micro-organisms; application of compost / manure to selected fields during seedbed preparation.

Purpose / effects

The main purpose of this measure is to enhance soil fertility and organic matter on selected fields.

Description / establishment

Composting is a natural process during which organic waste is biologically decomposed by micro-organisms. Organic residues are usually collected in a pit (locally called *medeku'e*) close to the farmer's house. These pits cover an area of around 2–4 m^2 and they are surrounded by stone bunds or walls. The following material is collected in the pit:

- manure of goats, cattle, donkeys;
- remains of burned materials / ashes;
- remains of fodder; straw from stable;
- any household waste (except strong paper, plastic, metallic items);
- plant residues / leaves;
- soil (optional); acts as a catalyst and accelerates the decomposition

Organic material is accumulated little by little, starting from June / July. Water (e.g. from roofs) is diverted to the pit to facilitate decomposition. Some farmers mix the material from time to time; others simply let it decompose without intervening. After a decomposition period of 3 up to 10 months, farmers let the compost dry and – usually between February and May – apply it on selected fields, initially in the form of small piles. During ploughing, the piles are dispersed using a spade, and then mixed with the soil. Application of manure depends on the type of crop sown, on the land redistribution cycle, and on crop rotation periods. Fertile *shiebet* fields are often prioritised, as they promise the best yield responses. The farmers were not able to specify application rates and quantities, since these depend on how much manure is produced and to which area it is applied. Manure is applied in greater quantities and more frequently to plots close to the settlement areas (Gedena zone). This land is not part of the crop rotation system and is therefore never fallowed (see "Crop rotation"). It has been intensively used and carefully protected and conserved for generations. Gedena soils generally have a high fertility status and are often sown with cash crops such as potato and onion, which require increased land management and application of manure. In the other zones, manure is applied only once every four

Local name(s):
midquae (manuring); *duk'e* (manure)

Land use type:
cropland

SWC category:
agronomic measure

Type of degradation:
soil fertility decline, organic matter decline

Combinations:
all types of SWC measures

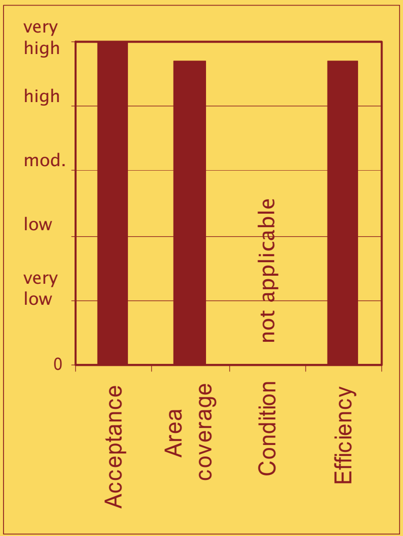
Approach:
indigenous

References:

Local key informant: No. 24, 84
See Table 45 , page 185/186

Geo-reference: n/a
See Table 47, page 195/196

Photos: SLM Eritrea photobase



Acceptance by farmers:

Acceptance of compost / manure application is excellent. All farmers practise it, although application is limited to one or few fields per household (mostly intensively used land close to settlement) as a result of a serious shortage of manure due to its use as fuel and to traditional grazing practices (open, uncontrolled grazing, see).

years, after the fallow period, when a new crop rotation cycle begins. Farmers assume that the manure – once applied – will maintain crop production for at least three consecutive years, i.e. until the next fallow period. Sheep and goat manure generally does last for 3 years, whereas cattle dung lasts only for 2 years and donkey dung only for 1 year (Freweini Negash, Helen Habte 1999). Manure application is strongly influenced by the land insecurity problem: farmers do not apply manure on leased plots or in the years preceding a land re-distribution.

Maintenance / modifications

Application is site-specific (on selected fields). On potato fields, farmers save manure by applying it only in the furrows, whereas for other crops it is usually mixed with earth and spread over the entire field. As a simplified form of composting, some farmers collect animal dung, strains and residues in a pile without constructing a special pit. Several farmers learned about adding urea to the compost (to speed up the decomposition process); however, they have not adopted this introduced measure.

Benefits / strengths

- Increases yields by up to 100%
- Fertility-enhancing effect lasts up to 3 years
- Easy practice
- Uniform distribution on selected fields
- Increases soil organic matter content and soil fertility
- Restores the soil structure
- Enhances infiltration potential and water holding capacity

Problems / drawbacks

- Shortage of animal waste for compost production due to: a) use of cattle dung as source of fuel (substitute for wood); b) use of organic material for house construction; c) lack of animals (poor farmers); d) reduction of potential number of animals due to drought and e) uncontrolled free grazing (dung is distributed randomly)
- Quantity of compost produced is not enough to manure several fields; usually only few fields or even one single field per household per year are manured
- Transport over long distances and distribution of compost on the field is labour-intensive
- Land insecurity doesn't encourage regular annual application of manure
- Problems related to specific ingredients of compost: Ashes cause dust when transported (therefore it is sometimes accumulated separately); some farmers fear that green, unwilted fodder plant residues could propagate in the composting pit and turn into weeds when dispersed on the field; chicken manure develops a bad odour when decomposing

Solid waste (from Asmara landfill)

A special form of fertilising is the application of "solid waste," or landfill compost, which is a product of urban landfill mining. This method was introduced from a neighbouring village through farmer-to-farmer knowledge exchange, i.e. not directly by the government. Farmers buy solid waste from the municipality of Asmara (*Scarico* landfill), and they have to pay the transport by lorry to the site of application. Disposed pharmaceuticals and bits of glass and metal have to be sorted out before the product can be scattered over the field. No technical assistance is provided from any sector or institution. Solid waste costs US$ 4 per lorry and is thus much cheaper than manure (US$ 17 per lorry). Moreover, its availability does not depend on animals. Additional transport costs are approx. US$ 30 per lorry for both. Solid waste is less effective than manure with regard to production increases, but nevertheless it is still profitable. A problem of solid waste is the fact that it contains different pollutants (e.g. disposed pharmaceuticals, batteries, etc.) which can affect animals or human beings and contaminate water. A collaborative research project on the potential risks and benefits of applying landfill compost for agricultural soils has been carried out by the College of Agriculture staff of the University of Asmara, SANDEC (Switzerland) and Maekel Zoba administration staff in 2004. This study revealed that landfill compost has noticeably improved the soil properties and crop productivity in the farmers' fields. However, the Asmara landfill compost also contains appreciable amounts of heavy metals (particularly lead, copper, zinc) which exceeded the admissible limits of the international standard. Such concentrations of heavy metals are believed to pose health problems and environmental pollution (Drescher et al 2005).

Left: *Stone mulching does not mean 'actively covering the field with stones'; rather, it means making use of a natural condition. Even though this farmer is establishing a stone bund, his field remains covered by stones.*

Right: *The greatest advantage of a high stone cover is the effect of moisture conservation: stones prevent evaporation of the water stored in the soil.*

Stone mulching

A 'passive' measure through which the naturally occurring stone cover on the soil surface is left there to protect the soil from evaporation and surface erosion.

Purpose / effects

The purpose of leaving stones on the field as a natural mulch is to protect the soil against erosion and conserve moisture in the soil by restricting potential evaporation. However, farmers do not perceive stone mulching to be a SWC measure.

Description / establishment

Large parts of the study area are naturally covered with stones of varying diameters. This stone cover protects the soil against erosion and evaporation. Although stone mulching is a natural phenomenon and does not involve active implementation by the farmers, in this study it is considered a local SWC practice, since farmers are clearly aware of its benefits and deliberately leave the stones on the soil surface.

Maintenance / modifications

Irrelevant.

Local name(s):
nay emni shfan

Land use type:
cropland

SWC category:
agronomic measure

Type of degradation:
soil moisture problem (evaporation), soil erosion

Combinations:
none

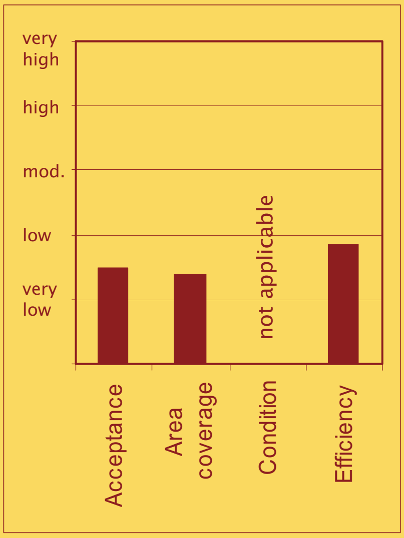
Approach:
indigenous

References:

Local key informant: No. 25, 65, 67
See Table 45 , page 185/186

Geo-reference: n/a
See Table 47, page 195/196

Photos: SLM Eritrea photobase



Acceptance by farmers:

Farmers assess both the acceptance and the area coverage of this measure as low to very low. This is probably due to the fact that they do not perceive it to be a SWC measure. However, stone covers as a natural phenomenon are fairly widespread and well-accepted. Stones are removed in areas where they are used in large quantities for the construction or maintenance of soil bunds and terraces, or where cash crops (such as potatoes or onions) are grown which require a low gravel content of the soil.

Benefits / strengths

- Prevents evaporation and thus conserves moisture in the soil
- Prevents surface soil erosion by water
- Increases yields (especially wheat and barley)

Problems / drawbacks

- Reduces soil workability
- Is not applicable for cultivation of cash crops such as potatoes, onions and garlic; these crops require hoeing by hand, which means that the stones need to be removed from the surface
- Hinders plant growth if stone cover is too extensive; loss of cropping area

Left: Introduced contour bunds complement existing local structures. Over time the bunds develop into terraces due to the constant downslope movement of soil particles (water and tillage erosion) and siltation behind the bunds.

Right: The effects of SWC demonstrated by a well-established stone and earth bund which traps the scarce rainfalls of the small rainy season and boosts production. Meanwhile, on the upper part of the field the conditions are too dry for plant growth.

Stone and earth bunds

Earth and/or stone embankments constructed along the contour lines to trap water and transported sediments.

Purpose / effects

Stone and earth bunds serve to trap and reduce run-off and increase infiltration, to accumulate eroded soil behind the bunds, and to reduce siltation of dams downstream. Contour bunds also have an important function with regard to runoff regulation: they conserve water in the upper part of the field (which naturally has a low water availability) while letting a sufficient amount of water pass to feed the lower part of the field.

Description / establishment

Farmers differentiate between earth (or soil) bunds, stone bunds, and combined stone and earth bunds. In practice most bunds are combined, which is why they are described in this report as sub-types of a single SWC measure. Combined stone and earth bunds are the most efficient and durable type of contour bunds. Where stones are scarce, bunds are built exclusively from soil; dimensions are the same as for combined stone and earth bunds. If stones are available in a limited quantity, the earth bunds can be stabilised with stones placed only on the riser. Grass can grow on the earth part, further stabilising the structure. Pure stone bunds without soil are built in flat areas prone to waterlogging, as well as in mountainous areas with shallow, stony soils where it is not easy or not reasonable to dig up earth. Stone and earth bunds are applied on slopes with gradients ranging between 3% and 50%. Spacing between structures is around 10 m on gentle slopes in order not to hinder ploughing with oxen, and narrower in steeper areas or in areas affected by floods. The vertical interval between structures is 1 m on slopes with gradients of less than 15%, and 2.5 times the depth of the arable soil layer on slopes steeper than 15%.

Bunds are built in the following manner: First, the contour is marked using a water-level. Then a small ditch (approx. 0.2 m) is dug out along the contour to build a solid foundation for the bund. Lines of stones are then piled up until they reach a width of 0.5 m and a height of 0.3–0.75 m. Stones should not be smaller than 15 cm in diameter. A ditch is excavated on the upper side of the bund, and the excavated earth is used to cover the bund on the upper side and seal the gaps between the stones to make the bund leak-proof. When built in externally initiated SWC campaigns, contour bunds are mostly established in combination with tied ridges.

Local name(s):

zala abhrsha (generally bund in cropland); *kinatawi zala*; *nay emni zala* (stone bund); *metrabawi zala*; *nay hamed zala* (soil bund)

Land use type:

cropland, afforestation areas

SWC category:

structural measure (permanent)

Type of degradation:

surface erosion by water, soil moisture problem

Combinations:

tied ridges

Approach:

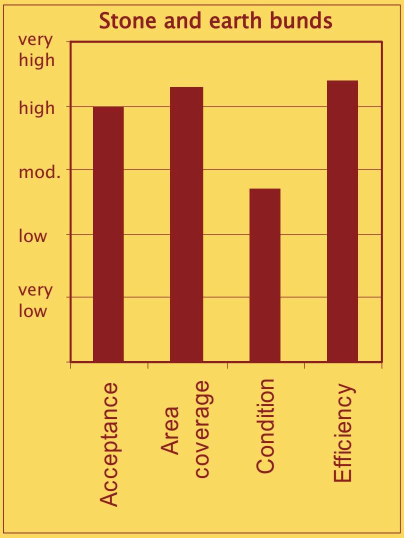
introduced

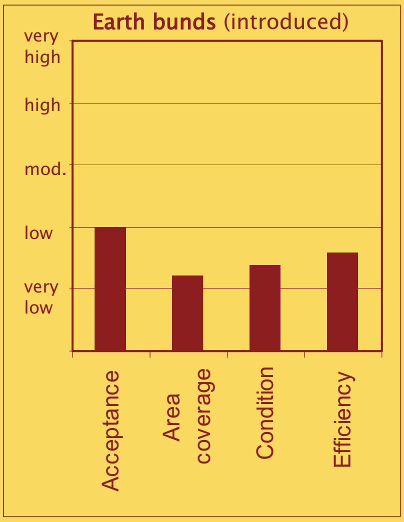
References:

Local key informant: No. 2, 4, 30, 37, 50, 57, 58, 64, 83
See Table 45, page 185/186

Geo-reference: Pt. 39–50
See Table 47, page 195/196

Photos: SLM Eritrea photobase
Techn. dimensions: based on Hurni 1986





Acceptance by farmers:

Stone and earth bunds have the highest acceptance rate of all introduced SWC measures. Their replication rate is high as well; convinced by the benefits, farmers integrate the structures into their land management system. Areal coverage is even very high: the bunds have become a symbol of many rural areas in Eritrea, giving the landscape its typical appearance. However, their maintenance and condition is only low to moderate, particularly in marginal areas or in community-owned afforestation areas. Many structures are damaged by grazing animals and through ploughing activities (by oxen and recently – in few cases – also by tractors). In contrast, pure earth bunds (as long as they don't mark traditional boundaries) are not accepted at all, due to various reasons (see problems / drawbacks).

Experts' view:

Physical structures such as contour bunds efficiently conserve soil moisture, also during dry periods. Extension workers at sub-zoba level should intervene to avoid damage to bunds caused by tractor ploughing.

Maintenance / modifications

Constant siltation makes frequent maintenance and enhancement of the bunds necessary. Over time, stone and earth bunds develop into terraces. Bunds and terraces on cropland are therefore often considered the same measure. After the rainy season re-arrangement of fallen stones and filling of gaps has to be carried out. These activities are considered an integrated part of land preparation, especially during the *tsig'e* period (first cropping season after fallowing). As long as there is no major damage (e.g. breached or collapsed terraces), maintenance work can easily be carried out by individual farmers. When farmers replicate the originally introduced bunds, they start by constructing pure stone bunds of variable dimensions (but usually smaller than the introduced bunds) and without a foundation. Soil is added later on simply by ploughing close to the bund.

Benefits / strengths

- High impact on moisture conservation (increased infiltration rates)
- Retards runoff
- Reduces soil erosion
- Accumulates eroded fertile topsoil, manure, and organic residues
- Reduces downstream siltation of dams
- Increases yields (30–50%); enhances quality and quantity of grains;
- Bunds are stable and durable; not affected by strong runoff
- FFW / CFW approaches provide compensation for high labour inputs
- Ground water recharge

Benefits specifically related to earth component:

- Basis for growth of grass, which further stabilises the structure
- Efficient retention of soil and water

Benefits specifically related to stone component:

- Regulates runoff / water availability on different parts of the field
- Prevents waterlogging (especially on flat land)
- Is particularly important for bund stability in areas prone to high and concentrated runoff (e.g. waterways)

Problems / drawbacks

- Open grazing: damage through wandering livestock
- Damage caused through ploughing activities (too close to the bunds)
- Damage caused through gathering firewood (tearing out shrubs or branches growing on bunds)
- Damage caused by extreme runoff after rainstorms
- Damage due to improper layout / lacking quality: if bunds are not along the contour, water flows laterally, accumulates, and breaches the structures; farmers have no individual interest in building high-quality measures on foreign fields during campaigns (main motivation are the incentives)
- New form of damage from passing tractors and lorries
- Loss of productive land (occupied by structures), especially when combined with tied ridges

Problems specifically related to stone component:

- Limited availability of medium to large-sized stones in some areas makes bunds susceptible to collapse
- Pure stone bunds do not conserve water well enough
- Damage caused by farmers removing stones in order to build their own structures (on the same field)
- Damage caused by removal of stones for construction of new road (by construction company)

Problems specifically related to earth component:

- Pure earth bunds can cause waterlogging (which, in turn, can lead to pests and weed development); excess water cannot be drained to neighbouring field (creates conflicts between field owners)
- Pure earth bunds are easily eroded and destroyed by strong runoff; if soil bund collapses at one point it can cause severe damage further downstream (see above)

Left: Tied ridges that have been newly established during the dry season, when other agricultural activities are reduced. Tied ridges are always built in association with bunds.

Right: Water is conserved in-situ, and lateral flow with a high risk of degradation is avoided.

Tied ridges

Long, semi-permanent ditches on the upper side of contour bunds, divided by small ridges into a series of 7-10 m long micro-basins; exclusively constructed in combination with earth bunds or combined stone and earth bunds.

Purpose / effects

Tied ridges serve the main purpose of in-situ water conservation. They impede lateral flow of runoff along the bunds, thus preventing accumulation of runoff at the lowest point and the risk of overflowing and breaching of structures. Furthermore, tied ridges increase runoff infiltration and trap washed-out topsoil in the ditch.

Description / establishment

Tied ridges are exclusively constructed in combination with earth bunds or combined stone and earth bunds. They consist of a long ditch on the upper side of the bund which is "tied," i.e. divided into a series of micro-basins by small side ridges. Initially the ditch is around 1 m wide and 30-50 cm deep. The small side ridges are laid out at a right angle, subdividing the ditch into 7-10 m long sections. The excavated earth is used to build the bund next to the ditch. Layout follows that of the bunds, i.e. the contour (see "Stone and earth bunds"). Spacing between the structures depends on the slope gradient, but should not be too close on agricultural land in order to facilitate ploughing with oxen. In steeper areas the spacing is closer. For details on spacing see description of stone and earth bunds (above). In forest and afforestation areas the same structures serve as micro-basins for water harvesting for tree planting (for differentiation between tied ridges and micro basins see Table 48, page 197).

Maintenance / modifications

Tied ridges are semi-permanent structures that - according to experts' view - need to be re-excavated as soon as the area behind the bund is silted up. However, farmers usually plough tied ridges once they are silted up, and sometimes even earlier. Maintaining them would limit plant growth due to waterlogging, and moreover, the soil accumulated in the micro-basins is very fertile and is needed to enhance crop production .

Local name(s):

m'esar terzi; *may zihz zala*

Land use type:

cropland; forestland (but for different purpose, i.e. water harvesting for tree planting)

SWC category:

structural measure (semi-permanent)

Type of degradation:

loss of topsoil by water erosion; overflow and breakage of structures, soil moisture problem

Combinations:

stone and earth bunds, grass strips

Approach:

introduced (implemented through CFW campaign), frequent replication by farmers

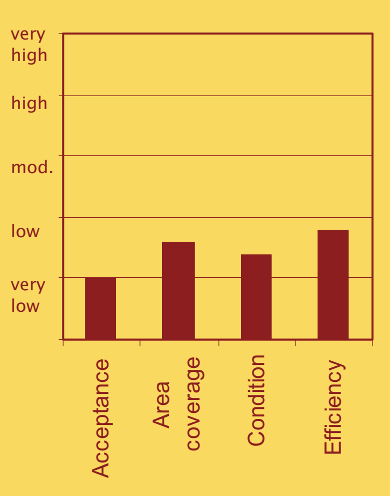
References:

Local key informant: No. 15, 32, 53, 56, 71, 73
See Table 45, page 185/186

Geo-reference: Pt. 51-59
See Table 47, page 195/196

Photos: SLM Eritrea photobase

Techn. dimensions: based on Hurni 1986



Acceptance by farmers:

Tied ridges were implemented uniformly throughout the whole catchment area in a collective effort during a campaign. Once the campaign was over, each individual farmer became responsible for their maintenance. Four years after implementation, tied ridges have almost completely disappeared from the agricultural fields, with only very few remnants left mainly on uncultivated land or areas of poor fertility that have not been ploughed during the past years. From the farmers' point of view, the benefits of this measure are negligible or outweighed by the problems it causes; therefore, they plough it. Tied ridges are not maintained. Acceptance is very low.

Experts' view:

Tied ridges are necessary to prevent water from flowing along the bunds, accumulating at the lowest point, and breaking the bunds (breaches). After some years they are silted up and can be ploughed. The adjacent bund needs to be increased, and the soil used to increase the bund can be excavated once more in the form of tied ridges. The loss of land is not greater than with common bunds, since the soil has to be excavated in any case. From the experts' point of view, the reasons for the disappearance of tied ridges are: 1) trampling by animals; 2) farmers' carelessness during ploughing. Implementation of bunds in combination with tied ridges led to a considerable reduction of runoff coefficients in the catchment compared to the preceding years (Burtscher 2000).

Benefits / strengths

- In-situ water conservation (improved water availability); infiltration and percolation leads to gradual moistening of the upper and lower parts of the field over several days (if soil characteristics are optimal)
- Improved water availability enhances effectiveness of fertiliser
- Accumulation of fertile soil
- Increases yields
- Prevents erosion and downstream dam siltation
- Prevents lateral flow of runoff, concentration at lowest point and ensuing breaching of structures (and further damage downstream)
- Provides basis for dense growth of grass (also in ditch); source of animal fodder

Problems / drawbacks

- High loss of productive land in area with severe land shortage, especially on flat and fertile areas: tied ridges and the adjacent bund have a total width of 2–2.5 m
- Soil excavated to establish tied ridges and the adjacent bund is fertile topsoil
- Complicates tillage practices with oxen plough on land that is already highly fragmented
- Causes waterlogging near the structures in certain areas, especially on flat *shiebet* land; sedimentation of fine and medium-textured soil particles leads to surface crusting.
- Fast siltation, low durability
- Maintenance would require high labour input (unpaid)
- Lack of knowledge transfer, lack of awareness


***Left**: Modified fanya juu with tied ridges and a second bund in a relatively plain area. These structures are effective in terms of soil and water conservation, but given their dimensions they occupy a high amount of productive land.*

***Right**: Bund and ditch covered by a dense grass cover that supports the soil and water conservation effect and simultaneously provides a source of fodder.*

Fanya juu terraces

Embankments along the contour made of soil, with an associated basin or ditch at the lower side to collect overflowing runoff; reduces or stops the velocity of overland flow and, consequently, soil erosion; *fanya juu* means "throw uphill" in Swahili.

Purpose / effects

Fanya juu terraces serve to protect high-potential land (in the dam irrigation area of Adi Asfeda) and efficiently conserve soil and water, also on steeper slopes.

Description / establishment

In 1999/2000, simultaneously with the construction of the dam in Adi Asfeda, the treatment of 10 ha of agricultural land with irrigation potential below the dam started. The area was first levelled with a bulldozer and then treated with a combination of structural measures such as *fanya juu*, *fanya chini* (equivalent to a stone / earth bund with tied ridges on the upper side) and vegetative measures, i.e. grass strips.

When constructing a *fanya juu*, the soil is moved upslope instead of downslope as is done when building the commonly promoted combination of level bunds and tied ridges. The water retention basin is thus formed at the lower side of the riser, which is beneficial on steeper areas with high runoff rates (risk of overflowing). Tied ridges are established every 7–10 m to prevent runoff from flowing sideways. *Fanya juu* can be applied on slopes ranging between 3% and 50% with soil depths of over 50 cm. The vertical interval between two structures is 1 m for slope gradients less than 15%. The height of a *fanya juu* bund is 50–75 cm, and the ditch is about 50 cm deep. The berm (space between bund and ditch) is at least 25 cm wide. The width of the ditch depends on the fertility of the soil. On fertile subsoil it may be very wide, and crops can be planted in the ditch. To simplify work and enable oxen to move from field to field, a gap can be left in the structure every 50 m.

Maintenance / modifications

Requires frequent maintenance activities (for details see "Stone and earth bunds" and "Tied ridges" above).

Local name(s):
fanya juu (Swahili term)

Land use type:
cropland

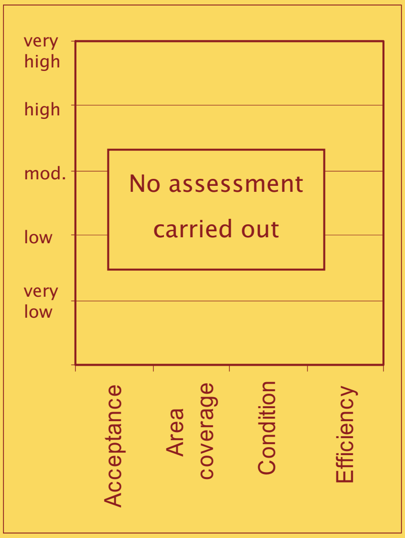
SWC category:
structural

Type of degradation:
soil erosion, soil moisture problem

Combinations:
grass strips

Approach:
introduced

References:
Local key informant: No. 30
See Table 45, page 185/186
Geo-reference: Pt. 60
See Table 47, page 195/196
Photos: SLM Eritrea photobase
Techn. dimensions: based on Hurni 1986



Acceptance by farmers:

Even though *fanya juu* (and also double ditches) have shown excellent results with regard to soil and water conservation on the test plots of the Afdeyu research station (Stillhardt et al 2002) they are not practiced in the study area. At the time of the study only one farmer was experimenting with *fanya juu* and double ditches on a very small plot. As the main reasons for this farmers mentioned 1) lack of extension and training, and 2) land loss.

Experts' view:

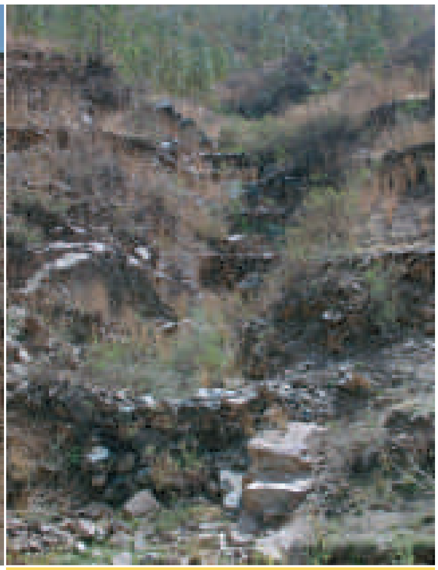
Fanya juu is an efficient measures on gentle slopes. Needs to be stabilised by grass. Can cause waterlogging (esp. in clayey soils). Not applicable on shallow / stony soils. Frequent maintenance is needed (dig out soil). Takes land, though it increases yields. Acceptance is low in case of land shortage, and insecure land use rights. Demonstration (on farm trial) to show benefits (yields and SWC) to farmers.

Benefits / strengths

- Effective soil conservation
- Increased water availability and thus better yields

Problems / drawbacks

- Loss of productive land
- Increases risk of waterlogging; fields become swampy; negative impact on plant growth
- Heavy labour input; applied only where soil is severely eroded
- Obstacle for cattle / oxen to pass



***Left**: Stone check dams are applied where concentrated runoff causes gully erosion – here an example on cropland. The gully bed at the lower side of the check dam – where the overflowing runoff hits the soil – needs to be protected (paved) with stones in order to avoid erosion.*

***Right**: In valley bottoms surrounded by steep slopes, a series of check dams is usually applied and connected to stone bunds laterally.*

Stone check dams

Stone wall built across the bottom of a gully or a small riverbed to control concentrated runoff.

Purpose / effects

Stone check dams serve to reduce runoff speed and prevent deepening and widening of gullies or even fill them up by trapping sediments (thus increasing the area of arable land).

Description / establishment

Stone check dams have to be solid constructions in order to resist high-runoff events. They are used to rehabilitate gullies, in which case one or two structures can be enough, and to stabilise narrow steep valleys, which usually involves a series of check dams. Better stabilisation of the structures is achieved by placing large stones in a foundation ditch. A massive stone wall is then built on top of this foundation, preferably using large stones, particularly at the base. Height and length of the check dams depend on the dimensions of the gully under treatment; their width is around 1 m. When built in a series, check dams have a vertical spacing of 1 m. It is possible to place an opening in the centre of the dam to safely discharge overflowing water at one point and avoid lateral erosion where the dam meets the gully. At these lateral ends, check dams often neatly continue in the form of stone bunds along the contour. It is very important to line the soil with stones at the base (on the lower side) of the check dam to protect it from erosion caused by overflowing water.

When only one or two check dams are built to stabilise a gully, it can be very effective to construct a supportive bent stone bund up-stream (see "Water diversion and drainage system") to reduce the speed of the runoff flowing towards the check dam.

Maintenance / modifications

Since check dams are placed in areas where concentrated runoff occurs, the area behind the dams tends to silt up rapidly, depending on the annual discharge and the rate of siltation. As soon as siltation reaches the level of the stone wall, the wall needs to be increased by adding stones on top.

Local name(s):
(nay emni) ketri / ketari

Land use type:
cropland, uncultivated land, afforestation areas

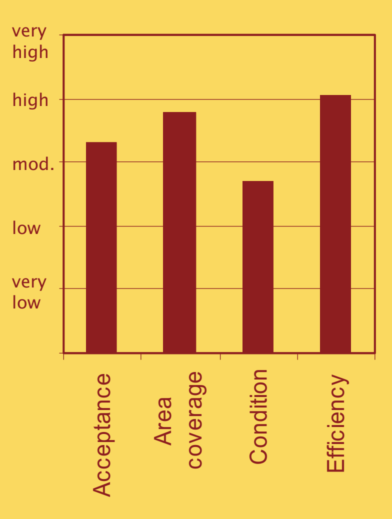
SWC category:
structural measure (permanent)

Type of degradation:
gully erosion

Combinations:
bent diversion bund (local measures)

Approach:
introduced; replication on farmers' own initiative

References:
Local key informant: No. 11
See Table 45, page 185/186
Geo-reference: Pt. 61-70
See Table 47, page 195/196
Photos: SLM Eritrea photobase
Techn. dimensions: based on Hurni 1986



Acceptance by farmers:

Stone check dams are generally well-accepted. This is reflected in the trend towards spontaneous adoption / replication by farmers on their own initiative. Although check dams are considered an important measure, the high labour input necessary to establish them poses problems. Stone check dams are rather widespread, but concentrated on specific areas, especially along valleys and in gullies. Their condition is poor to moderate. Lots of check dams are silted up and need to be enhanced. Maintenance is a problem in marginal areas and on communal land.

Experts' view:

Need of high quantity of large stones; needs training / technical assistance to be firmly constructed and maintained properly. The first year the height should be < 0.75m. Should be applied on watershed level; is very labour-intensive: needs incentives and group work. Application limited to where runoff accumulates (valleys, gullies), has to be supported by other measures.

Compared to establishment work, which is highly labour-intensive, maintenance is easy and fast. Farmers do it once a year and after heavy rainfall. Check dams have been replicated in great numbers by farmers. Sometimes they modify the concept by fortifying the base of the stone wall on its upper side. Stone walls also form an element of the package of combined structural measures applied in local gully/pipe rehabilitation (see page 63).

Benefits / strengths

- Decreases speed of concentrated runoff, controls gully erosion
- Sediment harvesting: accumulation of fertile soil
- Turns uncultivated land (valleys / gullies) into productive arable land through siltation
- Stabilises valley floors and prevents lateral riverside erosion
- Water conservation
- Off-site benefits: reduces downstream flooding and siltation of water reservoirs / dams.

Problems / drawbacks

- Requires frequent maintenance due to rapid siltation
- Heavy work (lifting stones); women or disabled people depend on support from village
- Poor accessibility of structures (steep valleys, enclosed areas)
- Lack of maintenance in forest areas (communal land) due to lack of individual responsibility

Hillside terraces

Structures built along the contour, where a strip of land is levelled for tree planting; mostly established on steep slopes in combination with micro-basins and area closure.

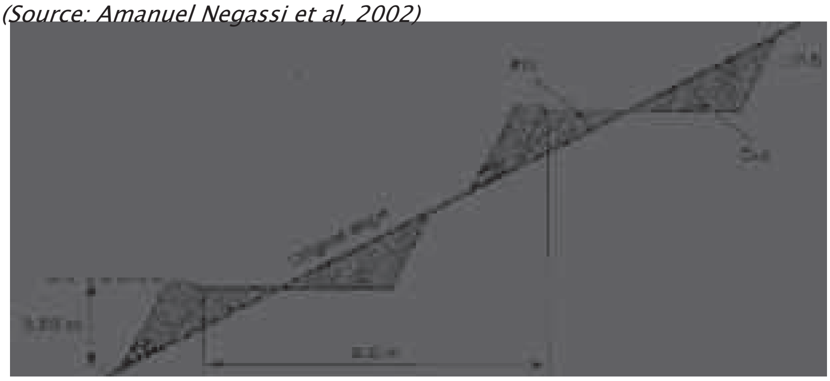
Purpose / effects

The main purposes of hillside terraces are retention of sediments and runoff on steep land, water conservation (in combination with micro-basins), and the provision of a level platform with favourable conditions for tree growth to accommodate tree seedlings.

Description / establishment

Hillside terraces are similar to stone and earth bunds on cropland. The dimensions of the structures are basically the same (1 m wide, 75 cm high), but the establishment method is different. While stone bunds gradually develop into terraces over time, hillside terraces are built and levelled at once, using the "cut and fill" method (see Figure 4 below).

Figure 4: *Establishment of hillside terraces (Source: Amanuel Negassi et al. 2002)*



Moreover, the spacing between structures is narrower: the horizontal interval between two terraces is 2–5 m. Hillside terracing is practised in mountainous areas with slopes steeper than 30%, for the purpose of reforestation, since these areas are not suitable for agricultural use.

In the study area both hillside terraces and stone check dams were constructed during the military campaign (*wefri lim'at*) in the dry

Left*: Hillside terraces stretch out to protect marginal areas from erosion. In most cases these terraces are combined with tree planting.*

Right*: Terracing of these slopes requires enormous labour inputs, which are available only within the framework of government-initiated campaigns.*

Local name(s):
kinatawi metrebawi zala / nay emni zala

Land use type:
afforestation areas

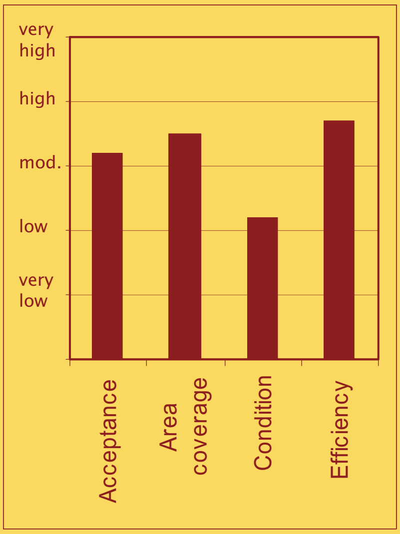
SWC category:
structural measure (permanent)

Type of degradation:
soil erosion by water, soil moisture problem

Combinations:
micro-basins, afforestation, area closure (cut-and-carry), check dams (in valleys)

Approach:
introduced

References:
Local key informant: No. 65, 67
See Table 45, page 185/186
Geo-reference: Pt. 71–74
See Table 47, page 195/196
Photos: SLM Eritrea photobase
Techn. dimensions: based on Hurni 1986



Acceptance by farmers:

Hillside terraces are a widespread measure, both in the study area and throughout the entire country. They are applied particularly on uncultivated steep areas in combination with afforestation. Acceptance is moderate; farmers do not see any direct benefit from investing labour in areas where they do not have any individual user rights and therefore concentrate their SWC activities on the cropland. Moreover, there is a lack of individual responsibility on communal areas. Maintenance of structures in these areas is therefore a serious problem. Many structures have never been maintained or repaired since their establishment, and their condition is generally poor.

Experts' view:

Essential on marginal, sloping land, in afforestation areas. Problems: labour intensive, high cost per hectare, remaining vegetation gets uprooted during construction, especially if they are closely spaced. Maintenance of structures on communal land needs to be encouraged, awareness-raising and incentives are needed.

period (May) of 1998. The pits for planting the tree seedlings were dug in June, and students planted seedlings (predominantly eucalyptus) during the students' summer campaign (*ma'etot*) as soon as the first rains came.

Maintenance / modifications

Hillside terraces require frequent maintenance, similar to stone and earth bunds. Breaches caused by wandering livestock and heavy runoff need to be closed every year, and silted-up terraces need to be enhanced. The harmful effects of poorly maintained terraces on steep marginal areas can be serious. Hillside terraces form a system together with other SWC measures, including micro-basins, tree planting, and area closure. The system can only work efficiently if all its elements are maintained in a functional condition. Maintenance is a great problem, since there are no individual user rights on the marginal forest areas where the measure is applied, and nobody feels responsible for doing the work.

Benefits / strengths

- Water conservation for tree planting on steep hills
- Prevention / reduction of soil erosion

Problems / drawbacks

- These structures, applied on non-agricultural land, have no direct (short-term) individual benefits
- Lack of maintenance due to community ownership: Nobody in the community feels responsible to maintain the structures

***Left**: Semi-circular micro-basins efficiently harvest water for individual trees. However, this measure is not widely used in the study area.*

***Right**: Layout of micro-basins is such that runoff passing between two microbasins is captured by the next basin below.*

Micro-basins (for tree plantation)

Half-moon-shaped (semi-circular) water harvesting structures combined with bunds / hillside terraces to collect runoff for tree plantation.

Purpose / effects

The main purposes of micro-basins are water harvesting and water conservation for tree planting.

Description / establishment

Micro-basins are implemented exclusively in afforestation areas. They are constructed manually, using earth and stone. Half-moon-shaped micro-basins are usually arranged as staggered stone and earth bunds (approx. 50 cm wide and 50 cm high) in the shape of semi-circles, approx. 3 m in diameter; they are placed in between contour bunds or terraces. Since they are often applied on shallow soils in marginal areas, the bunds are built from stones and then sealed by adding the earth that was excavated on the inside of the structure. Sealing the bunds with earth is essential to increase their water harvesting efficiency. Storage capacity depends on the diameter and depth of the pits and the height of the bunds. Excess water is discharged around the tips and is intercepted by the next row of micro-basins. A second type of micro-basin is widely used in combination with hillside terraces. These rectangular micro-basins are built in series along the edge of terraces or along bunds. They are practically identical with tied ridges – apart from their specific purpose to harvest water for trees and their area of application (afforestation areas). For technical specifications, see “Tied ridges”.

Maintenance / modifications

Micro-basins need to be re-excavated from time to time. The problem is that there are no individual user rights on the marginal forest areas where this measure is applied in combination with contour bunds / hillside terraces, thus nobody feels responsible for maintenance.

Local name(s):
gablawi zala; *frki werhi*

Land use type:
afforestation areas

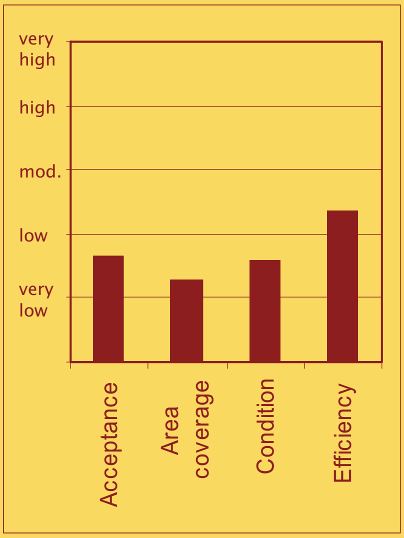
SWC category:
structural measure (permanent)

Type of degradation:
soil moisture problem, soil erosion

Combinations:
hillside terrace, afforestation, area closure, check dams (in valleys)

Approach:
introduced (by government order)

References:
Local key informant: No. 25, 65, 67
See Table 45, page 185/186
Geo-reference: Pt. 75–78
See Table 47, page 195/196
Photos: SLM Eritrea photobase
Techn. dimensions: based on Hurni 1986



Acceptance by farmers:

Area coverage is low. Semi-circular micro-basins can only be found in isolated forest areas. Rectangular pits (like tied ridges) are more commonly used for eucalyptus plantation. Their condition is very poor: most pits are silted up due to lacking maintenance. Micro-basins are generally not accepted.

Experts' view:

Micro-basins support tree planting through in-situ water conservation; applicable on gentle slopes, complements hillside terraces; low construction cost per hectare, low environment disturbance in constructing and easy to establish (not necessarily along contour). Not applicable on cropland (because of ploughing). They are used to harvest water for crops in drylands.

Benefits / strengths

- Water harvesting
- Reduced soil erosion

Problems / drawbacks

- Establishment of micro-basins is labour-intensive
- Lack of maintenance

***Left**: Large-scale afforestation programmes help to protect the dams downstream from siltation.*

***Right**: Cut eucalyptus trees start to regrow. Structural measures such as hillside terraces and microbasins are crucial to harvest enough water for the trees to grow.*

Afforestation and area enclosure

Tree planting in enclosed communal areas, often on steep slopes that are not suitable for agricultural activities, usually combined with implementation of physical structures.

Purpose / effects

Area enclosure and afforestation serve to regenerate the vegetation and improve the soil cover; other purposes are wood production for construction and as fuel; fodder production; reduction of runoff and soil erosion (through roots and soil cover); and prevention of downstream dam siltation.

Description / establishment

First planting activities were carried out in the 1980s. A large-scale government reforestation programme, including eucalyptus plantation and the establishment of micro-basins, started in 1992. One famous result of this programme near the study area is the TOKER forest, which was established to protect the TOKER dam. Another initiative started in 1998, when large parts of the Kelkel zone in Afdeyu were planted with eucalyptus in a student's summer campaign (*kremtawi ma'etot*). Afforestation (a vegetative measure) is always linked to area closure (a management measure). This is why they are described here as one single measure. In the study area the following species have been planted:

- *Eucalyptus globulus* (blue gum, *tsa'eda kelamitos*), exotic
- *Eucalyptus cladocalyx* (sugar gum, *keih kelamitos*), exotic
- *Acacia saligna*, exotic
- *Olea africana* (African olive), native
- *Juniperus procera* (pencil cedar), native
- *Dodonaea* spp., native

Eucalyptus is the dominant species. Before trees are planted, structural measures such as hillside terraces, contour bunds, check dams and micro-basins are built in order to stop erosion and promote water harvesting. The planting pits are dug before the beginning of the rainy season (June), so that the seedlings can be planted as soon as the first rains fall. Sugar gum is planted in poor, shallow soil, on steeper slopes, and is drought-tolerant; blue gum is planted in fertile soils (valley bottoms) and is not drought-tolerant. Spacing between trees is usually 2-2.5 m. The seedlings are provided by the MoA. After a minimum of 8 years the trees are ready to be harvested.

Local name(s):

mgrab (afforestation);

Land use type:

forest / woodlands (after tree planting); often applied on marginal / degraded land

SWC category:

vegetative and management measure

Type of degradation:

soil erosion by water, vegetation degradation

Combinations:

hillside terraces, micro-basins; cut-and-carry (stall feeding)

Approach:

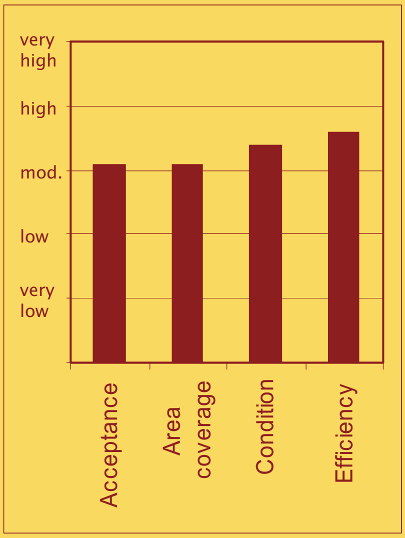
introduced (through campaigns)

References:

Local key informant: No. 1, 21, 25, 65
See Table 45, page 185/186

Geo-reference: Pt. 71-77
See Table 47, page 195/196

Photos: SLM Eritrea photobase



Acceptance by farmers:

At first, when the enclosures were established by the MoA, the farmers were reluctant to accept them. When user rights and management were handed over to the villages, the acceptance among farmers increased. Nowadays they benefit economically from the afforestation area by selling grass and trees. At the same time the area is conserved and erosion minimised. The condition of the afforestation areas is considered to be moderate to good; nevertheless, maintenance should be improved and dead trees replaced with new seedlings. There have been problems of illegal cutting.

Experts' view:

New seedlings are available free of charge from the MoA. Nevertheless, the community is showing no initiative. Awareness-raising and incentives are needed. Farmers need to be convinced to build and maintain SWC measures and continuously benefit from them. Benefits are on long term only, land ownership is a big problem: The forest land should be shared. Afforestation areas are beneficial as long as they are situated in mountainous areas. They have several advantages for farmers:

1) good timber (harvest after 5-7 years) and fuelwood;
2) source of fodder (which is expensive to buy);
3) income generation: high profitability of these products: good price on the market.

Maintenance / modifications

Newly afforested areas are closed for all kinds of use until the trees reach maturity. Initially, closed areas were managed and controlled entirely by the MoA. In 1994 this task – as well as the user rights – were handed over to the village: The community now has the right to use the trees and cut the grass according to its needs, but always collectively and never individually. A certain percentage of the money earned from selling grass and wood has to be deposited in the bank and is used for infrastructure development at the village level (e.g. electricity). A guard is paid by the MoA to watch the enclosed area. In afforestation areas, cattle grazing is generally prohibited, while collective cut-and-carry of grass is allowed during certain periods. The MoA now restricts its influence to guidance, technical assistance, payment of the guard and some incentives at the beginning. A technician visits the area sporadically to supervise the guard and examine the condition of the trees. When trees are to be cut, the village administrator has to ask permission from the government. Then the village elders cut the trees and distribute them equally to each household, regardless of household size.

Benefits / strengths

- Source of firewood, timber
- Fodder production: grass grows between the trees (cut-and-carry)
- Source of income (selling timber, grass)
- Improves micro-climate; conserves moisture; "those trees might bring rainfall"
- Soil conservation (in combination with additional measures)
- Increases soil fertility (directly through increased organic matter and/or nitrogen-fixing trees; indirectly through replacement of dung as a fuel with wood)

Problems / drawbacks

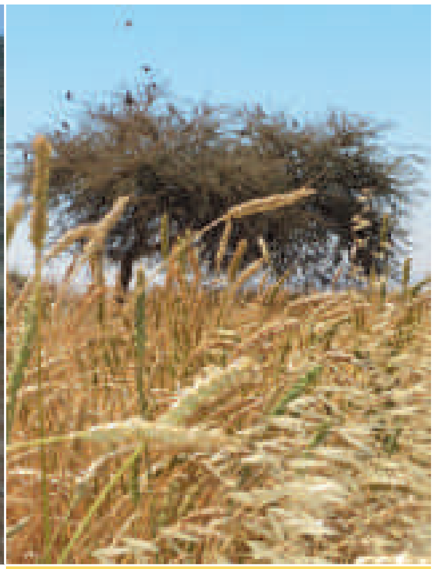
- Land use rights: because the afforestation area is communal, nobody feels responsible for maintenance (by contrast, individually owned trees around the houses are well-maintained)
- Cut-and-carry requires more labour input than open grazing
- Illegal cutting of trees
- Fast growing eucalyptus trees have a high rate of water consumption, negatively affecting water availability in the area

Individual tree planting

Along with the tree planting campaigns on communal lands, the MoA also supports individual tree planting by providing seedlings from its nurseries. In Afdeyu this approach was used successfully to reforest and protect the degraded area in the valley around the broken dam (see also box on page 46). In 25% of the villages in Serejeka Sub-*zoba* farmers own and use trees individually. Table 17 shows the average number of individually owned trees and the choice of species in relation to planting sites (sample: 84 households). The figures do not include any trees that are currently under communal ownership (externally-sponsored and externally-initiated approach). The number of these communally owned trees is far higher than that of the individually owned trees. However, farmers perceive the trees planted in FFW / CFW and other campaigns as communally owned trees that can only serve for communal interests. (Source: Iyob Zeremariam 2004)

Table 17: Individual tree planting in Serejeka zone (Source Iyob Z. 2004)

Planting site	Trees per households	Eucalyptus (%)
Home stead	4	51
River bank / swampy areas	11	97
Upper catchment terracing areas	7	95
Farmland / farm boundary	0	0



Left: *Acacia saligna is a native nitrogene-fixing species which is well adapted to semi-arid conditions and has multiple benefits.*

Right: *Agroforestry is a difficult endeavour. Acceptance among local land users is very low, since they perceive trees as having too many negative effects on crop production (e.g. harbouring birds, competition for water and nutrients, etc.).*

Agroforestry

Agroforestry system in which rows of acacia trees are planted along stone and earth bunds following the contour; spacing between structures is 10 m

Purpose / effects

Trees and shrubs on cropland serve to improve the soil cover and protect the soil from evaporation (improved micro-climate), as well as to reduce wind erosion; they provide a source of fodder and increase the organic matter content of the soil. Acacias help improve soil fertility through fixation of nitrogen[1].

Description / establishment

Acacia saligna seedlings were planted along stone and earth bunds on agricultural fields on a small area in Kelkel zone, Afdeyu. Acacia is a fast growing, drought-tolerant tree species that is adapted to shallow and poor soil and is able to fix nitrogen (http://www.pfaf.org/database/plants). The trees were planted at intervals of 10 m in order to avoid negative impacts on crop growth. Seedlings are provided by the MoA. The best time for plantation is at the beginning of the rainy season. Fertilising is not necessary.

Maintenance / modifications

No maintenance activities reported.

Local name(s):

nay agrab mesmer ab hrsha

Land use type:

cropland

SWC category:

vegetative measure

Type of degradation:

vegetation degradation, loss of biodiversity

Combinations:

stone and earth bunds

Approach:

introduced

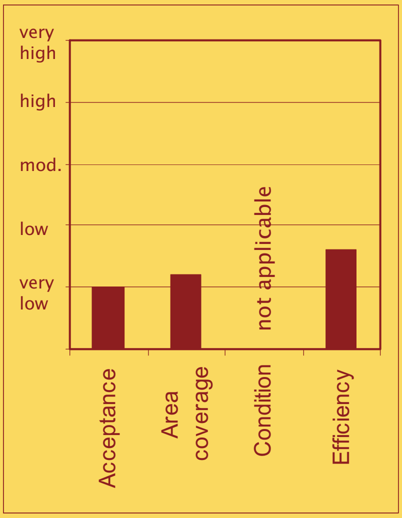
References:

Local key informant: No. 35
See Table 45, page 185/186

Geo-reference: Pt. 79
See Table 47, page 195/196

Photos: SLM Eritrea photobase

[1] expert's view



Acceptance by farmers:

Areal coverage of agroforestry is very low; it is limited to a very small area on marginal land far from the village. Trees and shrubs on cropland are not at all accepted by the farmers, since in their perception this measure is coupled with manifold disadvantages (see above). Moreover, farmers mentioned that MoA extension workers did not provide sufficient instruction / information and did not make enough efforts to convince them of the benefits of tree planting in agricultural fields.

Experts' view:

Important to increase vegetation cover on bare land. Use multipurpose trees (conserves soil and water, fuelwood, fodder, edible fruits, nitrogen fixing). Further benefits: organic matter, mulching, wind break. Main problems: Competition with crops, land tenure system (no long term user rights), land shortage (trees take land), grazing by animals. Trees can hinder ploughing activities. Pruning of trees help to avoid negative effects (nutrient and moisture competition, shading effect). Also: use shrubs or grass instead. Promote tree planting in gardens.

Benefits / strengths

- Acts as a wind break (protects against wind erosion)
- Increases soil organic matter content and soil fertility through residue decomposition (leaves)
- Source of fodder for cattle (leaves)
- Protects the soil from evaporation and erosion (fallen leaves act as mulch)
- Improved micro-climate, better rains (increased water availability)
- Shading effect minimises evaporation (improved micro-climate)
- Nitrogen fixation (expert's view)

Problems / drawbacks

- Trees provide a habitat for undesired birds who eat the seeds (panicles) of wheat and barley during the ripening stage (bird attacks); "trees in agricultural fields foster pests and insects"
- Shading effect affects crop growth (shortage of sunlight)
- Trees compete with crops for water and nutrients, leading to reduced crop production
- Gum dropping from trees such as eucalyptus affects crop growth negatively
- Takes a long time to reach maturity, benefits start only after land re-distribution; land tenure system does not encourage this type of long-term investment
- Land scarcity: "The trees will take land, we want to plant in our farm food crops rather than trees"
- Protection from grazing livestock is not guaranteed, since the area is not enclosed; trees may not grow
- Illegal cutting of trees
- Bunds are damaged during firewood collection (when removing branches / shrubs from the structures)

Left: *Grass strips on contour bunds have multiple benefits, but they are difficult to establish due to the prevailing grazing system in the area (uncontrolled / open grazing).*

Right: *Vetiver – planted on a contour bund – is one of four species used in Adi Asfeda*

Grass strips

Strips of grass (different species) on earth bunds along the contour.

Purpose / effects

Grass strips on bunds have multiple purposes: they 1) provide fodder for livestock, 2) slow down runoff and improve infiltration, 3) trap sediments, and 4) stabilise bunds with their roots. Vetiver is considered particularly advantageous when the focus is on soil and water conservation, whereas columbus and alfalfa are typically used as fodder species; elephant grass best combines all these benefits.

Description / establishment

In Afdeyu, vetiver (*Vetiveria zizanioides*) strips were introduced on a limited area in Grat Hamushte zone. Planting was carried out during the 1999 students' summer campaign, in collaboration with the MoA. Farmers were not involved. The introduction of vetiver has failed: today the grass strips no longer exist. In Adi Asfeda (west of Asmara), three other species have been introduced apart from vetiver: elephant grass (*Pennisetum purpureum),* columbus grass *(Sorghum almum)*, and alfalfa (*Stylosanthes humilis)*.

- Vetiver grass: Tall, stout perennial; older leaves are too tough to be used as fodder; withstands heavy grazing; has proved useful for erosion control; its aromatic roots are a source of vetiver oil (used chiefly in perfumery).
- Elephant grass: Robust perennial grass with a vigorous root system; grows up to 180–360 cm high; spreads slowly; withstands heavy grazing and provides a great quantity of fodder; is commonly used in a cut-and-carry system.
- Columbus grass: Fast-growing, high-yielding, palatable, short-term perennial, suitable for rapid grazing to help defray establishment costs; useful for silage; drought- and salinity-tolerant to some extent.
- Alfalfa: A self-regenerating, self-fertile annual or short-lived perennial legume; fixes nitrogen; adapts to low-fertility soils; free-seeding; palatability increases with age.

(Source: http://www.fao.org/ag/AGP/AGPC/doc/GBASE)

Local name(s):
nay sa'eri mekina'at

Land use type:
cropland

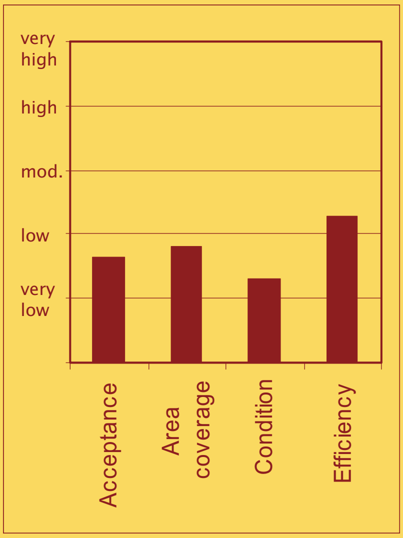
SWC category:
vegetative measure

Type of degradation:
soil erosion by water

Combinations:
stone and earth bunds, fanya juu

Approach:
introduced

References:
Local key informant: No. 26, 35,
See Table 45, page 185/186
Geo-reference: Pt. 80
See Table 47, page 195/196
Photos: SLM Eritrea photobase



Acceptance by farmers:

Remnants are all that is left of the grass strips planted in Afdeyu, but also in other sites visited during the present study (e.g. in Geshenashm). The grass strips disappeared during the initial phase as a result of drought, along with grazing and trampling by livestock. Although vetiver is relatively unpalatable, animals feed on it in dry years due to lack of alternative fodder species. Area closure would be necessary to protect the strips from livestock. Farmers did nothing to maintain the measure, as they were unaware of its benefits because they were not involved in planting and not informed about the management and the function of grass strips. Acceptance is low to very low.

Experts' view:

Grass strips were damaged (grazing, trampling) due to uncontrolled grazing; after the harvest animals graze on cropland, and although vetiver is relatively unpalatable, they graze it in dry years (e.g. 2002) when there are no alternative fodder plants. Recurrent droughts pose a great problem.

Farmers do not keep their animals in the house (to prevent uncontrolled grazing) for cultural reasons.

Farmers are not motivated to maintain or protect the grass strips due to the prevailing land use rights (with land re-distributions every seven years).

Elephant grass and vetiver seedlings are planted on the upper side of the bund with a spacing of 20 cm between plants. Columbus grass and alfalfa seeds are sown at the top of the bund. Planting is carried out during the rainy season. The MoA provides the seedlings free of charge.

Maintenance / modifications

In Adi Asfeda, the area is closed for grazing. Extra irrigation is not necessary; the grasses receive enough water when the field crops are irrigated. Animals are allowed to graze only at the time of ploughing; otherwise the grass is cut and carried. Gaps need to be filled to ensure effective soil and water conservation.

Benefits / strengths

- Strengthens the physical structure on which it grows (bund) by stabilising it with its root system
- Retards runoff and thus controls surface erosion by water
- Accumulates eroded sediments and increases soil fertility (locally, along the grass strip)
- Conserves moisture in the soil
- Provides animal fodder; withstands heavy grazing if well-established (vetiver, elephant grass)
- drought-resistant, rapid regeneration after dry period (vetiver)
- Can easily be transplanted from one location to another (vetiver)

Problems / drawbacks

- Not adapted to prevailing grazing practices (open grazing); requires area closure as a supportive measure (at least during the establishment phase) to protect the young plants against trampling and overgrazing by sheep, goats, and cattle; it would be preferable to plant grass strips in a protected area (e.g. afforestation area, in combination with micro-basins, half-moons, terraces, etc.)
- Drought / water shortage during the establishment phase
- Lack of knowledge / training: extension workers did not instruct farmers with regard to the management and functions / benefits of grass strips; as a result, farmers often plough too to close to the bund
- Elephant grass is climatically not adapted to the highlands: it is neither drought-resistant nor frost-tolerant
- Elephant grass provides a habitat for rats (main problem in Adi Asfeda)

***Left**: Bags of Urea and Di-Ammonium-Phosphate are sold at a subisdised price to farmers.*

***Right**: Farmers apply a 2:1 ratio of seed to fertiliser.*

Fertiliser application

Application of chemical fertilisers such as Di-Ammonium-Phosphate (DAP) and urea.

Purpose / effects

Fertilisers are applied to increase yields by improving the soil nutrient status and soil structure.

Description / establishment

Mineral fertilisers were introduced in the study area in the early 1980s to combat the problem of declining soil fertility caused by soil erosion, lack of organic manure, and shortening of fallow periods due to land scarcity. Common types of mineral fertilisers applied in the area are Di-Ammonium-Phosphate (DAP) and urea. Mineral fertilisers are seen as a short-term investment with an immediate impact which, however, is limited to a single cropping season. Farmers apply a 2:1 ratio of seed to fertiliser, which translates into 15-20 kg fertiliser/ha (if fertiliser is available).

Chemical fertilisers can be purchased once a year from the Serejeka Sub-*zoba* MoA branch at a subsidised price.

Maintenance / modifications

Not applicable (annual measure).

Local name(s):
konshim

Land use type:
cropland

SWC category:
agronomic measure

Type of degradation:
fertility decline

Combinations:
fallowing / ploughing system

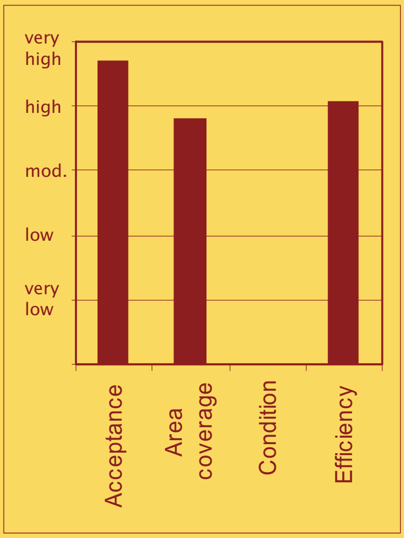
Approach:
introduced

References:

Local key informant: n/a
See Table 45, page 185/186

Geo-reference: n/a
See Table 47, page 195/196

Photos: SLM Eritrea photobase



Acceptance by farmers:

Application of chemical fertilisers is very well-accepted. Area coverage is considered high, but is currently limited due to financial problems despite subsidies (lack of funds to purchase external input).

Experts' view:

Farmers apply chemical fertiliser every year without knowing requirements. Ratios used today are still based on former Ethiopian data. Site-specific research (trials) should be carried out to assess soil nutrient requirement for different soil types and determine which fertiliser to apply where and at what ratio.

Benefits / strengths

- Increases soil fertility
- Increases production and thereby enhances food security
- Helps to increase the water retention capacity by keeping the soil moist after rains
- Softens the soil, thus improving soil workability
- Is particularly advantageous in flat areas where water availability is high (water is needed to make the fertilisers effective)
- Reduces risk of waterlogging

Problems / drawbacks

- Limited availability: chemical fertilisers are released only once a year; many farmers cannot afford to buy sufficient fertiliser
- Requires water in order to be efficient; is difficult to apply under erratic rainfall regime

Characteristics and status of SWC measures

Comparison of local and introduced SWC measures

The following two tables provide an overview of the criteria underlying the distinction between local and introduced measures in the study area. For more details consult Appendix 2 (page 197).

Table 18: General characteristics of local and introduced SWC measures

	Local SWC measures	External / introduced SWC measures
Design	By local farmers	By engineers, development planners
Purpose	Multiple purposes (multi-functional), depending on setting; often fertility management and water harvesting	Soil and water conservation
Design features	Flexible, subject to modifications, site-specific, and adapted to local (and seasonal) variation of biophysical and socio-economic factors; seasonal, semi-permanent or permanent	Fixed, standardised, homogeneous design, applied at a large scale; permanent
Area of application	Cropland	Uncultivated hillsides (afforestation areas, grazing land, marginal land), cropland
Implementation	Incremental, integrated in existing farming system, in accordance with household labour availability, individual	One-time, collective campaign work; separate activity (isolated, not integrated in farming system) causing extra costs
Approach	Innovation by farmers, farmer-to-farmer extension, spontaneous adoption, no external support or assistance	Large-scale campaigns providing incentives such as food-for-work or cash-for-work (employment-based) and technical assistance
Labour input	Variable, generally low	High
Inputs and costs	Resources available on farm, low-external-input system, low-cost technology	Can involve considerable external inputs, e.g. fertilisers, high costs
Returns	Mostly short-term	Often mid- / long-term

Source: based on Scoones et al 1996, in Freweini Negash and Helen Habte 1999, modified and complemented by authors

Table 19: Technical features and design of local and introduced SWC measures (Example: Stone and earth bunds, stone terraces)

Local structures	Introduced structures
• Only constructed on specific sites, typically in valleys and near the village (Gedena zone) • Mostly staggered, not continuous • Not, or only approximately, along contour; traditional bunds and terraces are often straight, even in valleys; particularly soil bunds developed from field boundaries that were not ploughed over a long period • Traditional terraces can reach high vertical intervals (1 to max. 5 meters) through continuous upgrading over decades • Traditional stone bunds have often undergone development into forward sloping terraces and finally into level bench terraces • Traditional terraces are often abandoned, with new introduced bunds constructed at their base, for the following reasons: (1) to follow the contour line; (2) to make use of fertile soil that was not used for many years; (3) to reduce loss of land (as terrace develops, riser occupies more and more land); this is a typical failure of project treatment and can encourage gully development	• Continuous over long distance • Introduced bunds often branch off from original structures • New bunds are often constructed at the base of abandoned traditional terraces (which were not laid out along the contour) • Introduced bunds often extend into the lateral parts of valleys (while traditional structures protected only the valley itself) • Introduced bunds also extend into marginal land – rocky, steep and uncultivated areas with shallow, unfertile soils – and into flat areas (full area cover) • Laid out along the contour; in valleys, curved introduced bunds typically cross straight traditional structures • Bunds have not developed yet into level bench terraces • Structures are closely spaced and have lower vertical intervals than traditional terraces

Potentials and limitations of local SWC measures

Local SWC measures make use of experience and knowledge accumulated by rural people over generations. They are the result of a gradual learning process based on constant observation and experimentation, and are therefore continually subject to modifications and further development (but not rapid changes). Local practices are thus well-adapted to the local ecological and socio-economic circumstances. Yet local knowledge on SWC has often been ignored by extension agents and experts. The fact that land degradation, and soil erosion in particular, continues to be a major problem, has led to the conclusion that farmers lack awareness, knowledge and means to tackle the problem. Projects thus focused on external solutions. However, standard solutions do not take into account specific local ecological and socio-economic conditions. The fact that farmers' needs are often not considered during the planning stage of SWC projects is likely to be one of the main reasons for low adoption rates with regard to introduced technologies – or even the complete failure of initiatives. (Krüger et al 1997)

In the context of the current international discourse, which emphasises sustainable agricultural production, many researchers have indicated in their findings that local farming practices in Africa are inherently geared to sustainability. Moreover, experience has clearly shown that the reason for the success of certain projects in rural areas lies in the fact that they integrated local knowledge and practices at every stage of planning and implementation (Krüger et al 1997). The non-consideration of farmers' opinions, local knowledge and thus site-specific experience has led to severe problems of acceptance and adaptation of SWC measures (Mitiku et al 2006).

Nevertheless, local systems also face constraints. People learn about local measures by using them, by access to existing examples (observation and replication), by practising and by gathering experience. Extension takes place within existing social relationships on household and on village levels. These learning and extension methods have limitations when applied to a higher scale: transfer of local knowledge to other areas where people are not experienced is difficult, as there is no information material explaining the concepts and no quantifiable procedure as a basis for adoption of measures to specific local conditions. Geographical or cultural barriers therefore limit transfer of local concepts and measures to other areas. Another limitation of local systems results from the fact that the process of adaptation to environmental change tends to be slow. These systems therefore pose problems when there is a need for reaction to rapid changes, e.g. an abrupt increase in pressure on marginal, sloping land (Krüger et al 1997).

Since SWC activities in local systems are often carried out individually, success of implementation depends largely on household settings, i.e. on preferences, needs and options of the individual household. Thus, on catchment level, the effectiveness of SWC measures is lower, since structures are not continuous and do not cover the whole area.

In conclusion, neither local approaches nor introduced technologies alone can solve existing problems. Both approaches were neither a complete failure nor a complete success, but both bear many lessons to be learned for the future from their merits and demerits. Successful integration of the two approaches could be the key to sustainable land use (Yohannes and Herweg, 2000).

Photo 18: *"Individual" means "limited to one's own plot": The structures implemented by a local farmer end at the field boundary.*

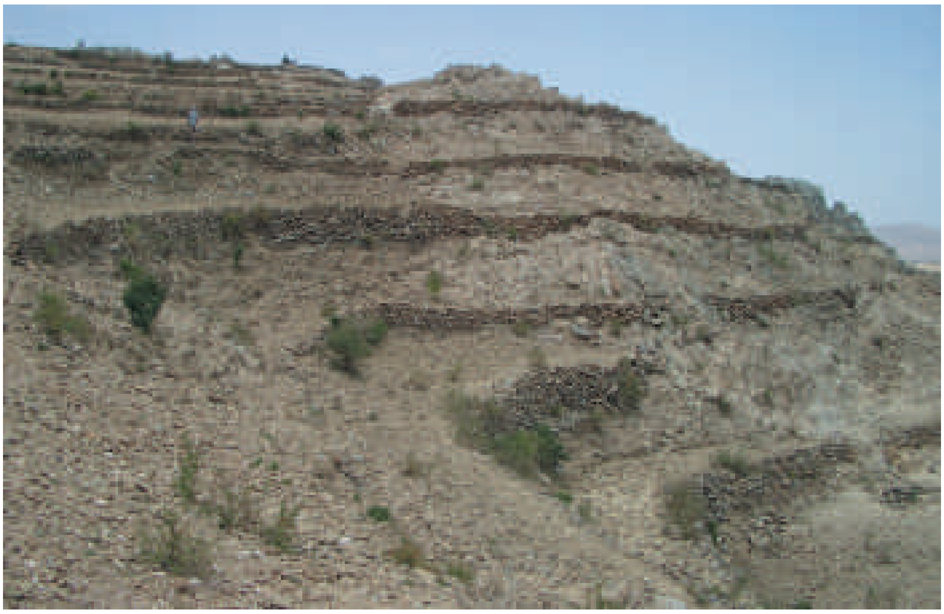


Photo 19: *Closing the gaps: Introduced stone bunds extend into the steep, rocky slopes of uncultivated marginal land.*

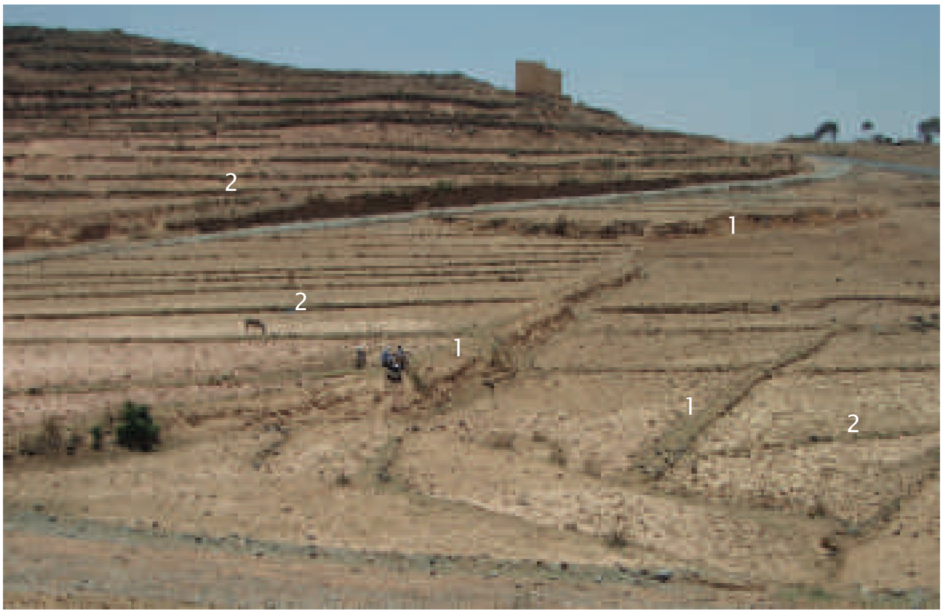


Photo 20: *Different directions: traditional structures (1) follow the field boundaries and not necessarily the contour lines. They clearly contrast with the level bunds (2) introduced on external initiatives.*

The importance of soil fertility management in local soil and water conservation

Soil fertility management is a very important aspect of local conservation systems. The primary purpose of many traditionally developed techniques is to maintain or increase production, whereas soil conservation is often an unintended but valuable side-effect. Against the background of increasing land fragmentation and land shortage, and, consequently, a trend to intensify land use and expand into fragile marginal areas, fertility management becomes even more important as an aspect of soil and water conservation.

Before inorganic fertilisers were introduced to the area, local farmers had developed a range of mainly agronomic techniques to maintain or improve the nutrient status and soil organic matter on their fields (for detailed description, see "Inventory of local and introduced SWC measures", pages 52 et sqq.).

- Crop rotation / fallowing: Rotation among a range of crops with different nutrient requirements helps to avoid unbalanced depletion of soil nutrients. Every four years, land is kept fallow during one year. This allows organic matter content and nutrient status of the soil to regenerate, and at the same time, top soil structure is restored.
- Collection of manure, production of compost, and their application on selected fields provides precious nutrients to the soil. Compost and manure are applied particularly in the Gedena zone, which is located very close to the village's residential area and, contrary to the other village zones, is used intensively and continuously without fallow periods. In the other zones, farmers apply manure only in the first cropping season after fallow, if at all.
- Mixed cropping is usually practised during the third cropping season after fallow (*salsien* crop rotation period). Farmers in the study area mostly mix wheat and barley, a crop association locally called *hanfets*, but also beans and maize. Mixed cropping minimises the risk of total crop failure, and legumes help to fix nitrogen in the soil.
- Semi-permanent soil bunds which have not been used for production for one or more years, along with the fertile topsoil that has accumulated behind them, are dismantled, ploughed and incorporated to the soil.
- Farmers use site-specific planting strategies to cope with different fertility levels: they select suitable crops according to the fertility status and soil type of a field, e.g. undemanding crops like linseed for poor soils.

These agronomic measures are directly linked to the management of nutrient status and organic matter. For the farmers in the study area, which is characterised by a semi-arid climate with low and erratic rainfalls, the availability of water is a crucial aspect of soil fertility. They have therefore developed a variety of structural and agronomic measures to enhance water availability (for detailed description see "Inventory of local and introduced SWC measures", pages 52 et sqq.).

- Stone terraces increase infiltration, improve water conservation, and reduce washing away of applied manure and loss of fertile topsoil.
- Diversion and drainage systems distribute available water evenly and thus increase water availability on dry areas.
- Various ploughing activities, including deep ploughing, are used to increase infiltration and help distribute available water evenly.

A serious problem regarding soil fertility is the lack of manure. The commonly practised system of open (uncontrolled) grazing does not allow for well-directed application of manure on specific fields, and complicates compost production. Particularly the widespread habit of using animal dung as an alternative source of energy (to replace fuelwood) is a highly limiting factor for restoration of fertility status on the fields. Moreover, livestock numbers are small, and the animals temporarily migrate from the village to other areas (e.g. the eastern escarpment).

Lack of manure is partly balanced by the application of chemical fertilisers – the modern approach to tackling the soil fertility problem. Fertilisers such as DAP and urea are offered by the Ministry of Agriculture every year at a subsidised price. Although farmers in the study area are generally well aware of this method, many of them cannot afford the expensive external input.

Photo 21: *The collection of dung to be used as fuel for cooking is the major reason for lacking manure application on the fields. Manuring would be highly needed to improve the soil fertility of cropland.*

Current status of SWC measures

Farmers generally reckon that from a quantitative point of view, the number of SWC measures implemented is sufficient to protect their fields. Exceptions to this statement were made with regard to certain specific places, where there is a need for the construction of new or additional structures (e.g. additional bunds on certain slopes, or additional check dams where gullies have formed).

Regarding the condition or quality of existing SWC measures, farmers diagnose a general lack of maintenance – mostly referring to structural measures. They see an urgent need for improving the condition, and thus the effectiveness, of existing measures. Particular emphasis is put on the need for repairing damaged structures: gaps in bunds must be closed, since breaches lead to concentrated runoff, resulting in gully erosion, and can cause fatal damage on fields downstream; many bunds are silted up and need to be upgraded to avoid overflowing during the rainy season.

Farmers see various reasons for the bad condition of SWC measures:

- natural causes, such as high-intensity rainfall / floods causing damages
- management practices, particularly grazing practices (open grazing)
- paths crossing the structures, causing gaps in the bunds (makes annual maintenance necessary)
- poor construction (motivation based solely on incentives during mass campaigns)
- lack of regular maintenance
- lack of manpower, tools and knowledge

Spatial distribution of SWC measures

Maps 3–5 on page 153 sqq show the spatial distribution of vegetative and structural SWC measures in the study area. Agronomic measures were not mapped since they are usually applied seasonally (i.e. they are not visible in the field during large parts of the year) and – being an integrated part of farming activities – many of them are applied generally to cropland.

Map 6 shows the condition of SWC measures and degradation sites. On Map 8, layers of condition and soil fertility were overlaid in order to find correleation between these two layers.

Acceptance of SWC measures

Introduction

The inventory of SWC technologies has clearly shown that certain measures, both introduced and local, are widely practised by the farmers in the study area, while other measures that were once implemented on a broad scale have disappeared almost completely. This raises some basic questions:

- What are the reasons behind success or failure?
- What makes a technology acceptable from the land users' point of view?
- Which are the essential criteria determining acceptability of SWC measures in a given environment?

Definitions

The two terms – acceptance and adoption – are often used as synonyms, which is how they are handled in this report as well.

Adoption is defined as the appropriation of an innovation, i.e. the act of bringing it into general use, particularly with little or no change in form (PRNV 2000). Thus, adoption implies the presence of an innovation (e.g. a SWC technology). This innovation can be introduced by external actors (e.g. through development projects), or it can arise from experimentation by land users at the local level. It can spread as a result of active promotion or spontaneously (e.g. through farmer-to-farmer extension). However, the concept of adoption – or its opposite, rejection – does not fully reflect reality (Stillhardt et al 2002). A SWC measure is hardly ever adopted and implemented exactly in the form promoted. When the concept or the idea of a technology is accepted, it will usually undergo a process of *adaptation*: land users modify the technology, adapting it to the local conditions and their individual household needs (Herweg 2005, personal communication). Adaptation is a continuous process of participatory technology development, a procedure of learning, with phases of modification, assessment and improvement. This may involve certain changes in its design or the inclusion of specific supplementary technologies. Where traditional or local technologies have been maintained to the present day, the question is how these have evolved into their present form (WOCAT 2003).

Two types of adoption can be differentiated:

- Spontaneous adoption: voluntary adoption of a technology without external assistance or support other than technical guidance (WOCAT 2003)
- Incentive-driven adoption: implementation of a SWC technology with financial and/or material support (WOCAT 2003)

Indicators of acceptance

Important indicators for the acceptance or adoption of a SWC measure are the following:

- The rate at which the measure is replicated on the farmers' own initiative, i.e. the rate of replication / reproduction without external support (spontaneous adoption).
- The level of maintenance of a formerly implemented measure, i.e. the condition a given measure is in; structures that are damaged, silted or even removed are indicators for poor maintenance, and thus low acceptance.
- The area coverage of a measure, or the number of land users who apply the technology (in relation to land users who do not apply it) in a given area. While the rate of replication (see above) is a dynamic variable, area coverage would be the result of the process, or its status at a particular time. This aspect also has to be considered in connection with the level of maintenance. If a technology is widespread but poorly maintained and in a bad condition, this means that farmers are not motivated to maintain it. In this case the technology cannot be considered "adopted."
- The degree to which land users modify the original design or shape of a measure (adaptation) gives an indication of the acceptability of the introduced measure in its original design; often the process of adaptation to local needs precedes adoption.

The level of acceptance or adoption is high when farmers maintain and reproduce a SWC measure on their own initiative. Introduced measures can be considered well-accepted in cases where the farmers have gradually developed a feeling of ownership and incorporated establishment and maintenance activities in their farming calendar. This means that they have “adopted” the SWC measure in question, now using and maintaining it without external support.

Photo 22: *Damaged stone and earth bunds: Whereas stone and earth bunds are generally well-accepted, they may be poorly maintained in marginal areas. This shows that the problem of acceptance is also site-specific.*

Acceptance and sustainable land use

Acceptance and adoption of SWC measures plays an important role in the concept of sustainability. Only if farmers are convinced by the functionality and the positive effects of a technology, and only if its benefits meet the farmers’ needs, will they accept it and be interested in maintaining it and keeping it fully functional and effective. Proper maintenance, in turn, is necessary to sustain positive effects, while badly maintained SWC measures can cause more severe damage than would have occurred if the field was left unprotected. Acceptance is thus a basic prerequisite for the sustainability of SWC measures.

Land users in the study area are generally subsistence farmers, i.e. their livelihood depends – more or less directly – on agricultural production. Soil productivity is therefore crucial, and sustaining and/or increasing yields has a very high priority. Farmers’ perceptions with regard to soil and water conservation activities focus on production rather than preventing soil loss. The potential of a given technology to maintain or increase yields is thus a major aspect determining its acceptance.

“The determining factor for high or low yields is to have good bunds in a field. Then the field will accumulate soil and water and it will produce a high yield…” (local key informant, 2004).

“You eat what you invest” (local key informant, 2004).

However, acceptance of SWC measures is based on much more than just their effectiveness in enhancing production. The interviews conducted with farmers in the study area showed that there is a wide range of different factors influencing the acceptance of a SWC measure, positively or negatively (see following section).

Parameters influencing acceptance of SWC measures

Farmers' perceptions

Farmers' perceptions regarding the importance of SWC measures and the reasons behind the lack of maintenance differ within the community. Based on their perceptions, the farmers can be divided into 3 groups:

1) Farmers who invest regularly and substantially in SWC, completely on their own initiative and on an individual basis: the so called "hard workers"
2) Farmers who do not invest in SWC activities on an individual basis due to a lack of interest or awareness
3) Farmers who are not able to invest in SWC activities due to age or weakness, female-headed households

The points listed and specified below express the general opinion of the farmers living in the study area (as derived from individual interviews and group discussions). This general opinion is often not shared by the "hard workers," who consider regular work on SWC measures necessary for keeping their most valuable basis for production – the soil – in a good condition, as well as for creating ideal water availability conditions. According to them, SWC is a matter of attitude and commitment: each farmer (apart from the disabled) can do it on his own if he is really willing to. Opposing opinions are mentioned wherever relevant in the specifications below.

The following results are based on the analysis of 40 individual interviews, as well as group discussions held during two PRA workshops.

Limitations of the establishment and maintenance of SWC measures

The farmers in the study area were asked to list and rank the limitations regarding SWC activities. The problems listed below – as perceived by the farmers – refer mainly to structural measures, which are considered the "classical SWC measures", whereas agronomic measures tend to be excluded, since they are mostly local and thus well-adapted and integrated into the local farming system. The various factors mentioned are often interrelated. For a comparison between local and external perceptions see Table 20 on page 117.

Major limitations of SWC activities:
- Importance of off-farm income
- Lack of incentives
- Lack of manpower
- Attitude
- Insecure land use rights (periodical land redistributions)

Minor limitations of SWC activities:
- Loss of productive area (land shortage)
- Lack of collaboration and collective efforts
- Lack of knowledge and awareness
- High costs and low availability of inputs
- Low effectiveness of SWC measures
- Ecological disadvantages
- Lack of legislation
- Grazing practices
- Cultural aspects
- Low productivity of a site / expected yields

Further limitations (as observed by study team):
- Poor accessibility of some sites
- Lack of land users' involvement in planning, implementation and evaluation

Importance of off-farm income

Since farmers are facing serious land shortage, soil fertility problems, a high risk of production failure (in a semi-arid zone with a high climatic insecurity), and limited options to intensify land use, they can no longer rely on traditional subsistence farming for their survival: they are forced to diversify their livelihood strategies and look for alternative sources of income to cover household needs. Moreover, a diversified strategy where income generation does not depend solely on selling agricultural products also provides more flexibility, allowing farmers to sell their products at a time when prices are higher. More and more farmers therefore try to focus on off-farm activities to improve their livelihood and increase food security. Attracted by the proximity of Asmara, farmers leave the village to look for jobs in the city. However, the growing importance of off-farm income leads to a decrease in the importance of agriculture. As a result, farmers become less interested in investing into SWC and reduce their investments in terms of time and manpower. Temporary off-farm activities are most sought during the dry period of the year (Jan–April), when field activities are less important; however, this is exactly the time when conservation activities are usually carried out. Often fields are rented out to other farmers – who are even less interested in investing into conservation measures (due to their short-term perspective and insecure land user rights). Another problem caused by the trend towards off-farm activities is the gradual disappearance of traditional knowledge about conservation practices.

This view can, however, be countered with an interesting opposing hypothesis: When farmers earn extra off-farm income, they are in a better position to invest in their land, for example by adding external inputs (e.g. fertilisers), or hired labour. Possibly, farmers simply do not earn the critical minimum necessary for investing in their land since off-farm income is often not even sufficient to ensure food security (expert key informant, 2004).

Lack of incentives

The use of incentives is a sensitive issue, and it is very much linked to the importance of off-farm income. Maintenance of SWC measures is based on individual initiative, i.e. each farmer is responsible for maintaining measures on his own fields. For the establishment of SWC measures on other people's land, as is done in campaigns, farmers need to be motivated with incentives. However, incentive-based campaigns (FFW, CFW) have created an attitude of expectation among the farmers: based on the campaign experience, they perceive soil and water conservation as an extra activity and means of income, rather than an integrated part of their general farming activities. Young farmers in particular have grown up with the idea that SWC is paid work which is carried out during campaigns rather than individually. This "receiver mentality" paralyses farmers with regard to individual initiative and innovations. Investment in conservation stops upon the termination of incentive payments. Particularly structural measures requiring a high initial labour input are acceptable only as long as an incentive is provided.

Photo 23: *Lack of incentives? Lack of manpower? Lack of secure land use rights? A discussion about the possible reasons behind the overdue rehabilitation of a terrace seriously affected by pipe erosion.*

Both aspects discussed so far – off-farm income and incentives – are closely linked to the importance of **short-term benefits**. The farmers' planning horizon focuses on the near future, giving short-term returns a critical importance. However, in most cases SWC (introduced measures) is not directly profitable. Short-term benefits (in terms of yields) are not high enough; consequently, SWC is not perceived as a priority. Against this background, incentives become relevant for mid- to long-term planning. Especially farmers who gain a substantial part of their income in off-farm jobs are not willing to invest labour into agricultural activities without being able to expect short-term returns.

Lack of manpower

The majority of the young men in the study area are absent – doing military service in the national army. The remaining village population consists mainly of elderly people, disabled people, women, and children. The community has thus been confronted with a serious loss of those of its members who were normally actively involved in field work. The labour force needed for the implementation and maintenance of SWC measures is no longer available. Particularly measures requiring a high labour input have become a problem for old, weak or sick persons, as well as for female-headed households.

The problem of labour force unavailability is further aggravated by cultural restrictions at the local level (see "Cultural aspects", page 115) and by the involvement of farmers in other activities, such as:

- temporary off-farm activities (during the period of the year when SWC activities are usually conducted) and permanent off-farm activities;
- temporary migration to remote farming areas (only few farmers);
- school (students);
- commitments and tasks in the village (priest etc.) or social activities (burials etc.).

Some farmers claim that the lack of manpower (or lack of time) is not a major constraint, at least not for those who actively cultivate their fields. These farmers have integrated SWC maintenance in their daily work. They claim that construction and maintenance activities requiring a higher labour input can be carried out in the dry season (Jan–May), when other field activities are reduced to a minimal level, and that those who go to school (children and young people) can help during their leave. They say that SWC is more a question of attitude than of availability of time and labour force.

Photo 24: *Individual initiative might have reached its limits and group work is likely to be needed in case of highly labour-intensive activities, such as the rehabilitation of a collapsed terrace.*

Attitude

"There is no bad land, only bad man!" (local key informant)

The attitude of each individual farmer was frequently mentioned as a major driving factor for the acceptance of SWC activities. Farmers reckon that investments into SWC activities depend on their personal commitment and interest to continually maintain what has been implemented. For some farmers it is even a question of honour to keep their land in a good condition for the coming owner at the time of re-distribution: *"It is good to hand over the land in a good condition, to be remembered as a good person!"* (local key informant)

These farmers perceive good maintenance of SWC measures as a kind of social obligation and think that poor maintenance would reflect negatively on their character and give them a bad reputation. Nevertheless, "lack of interest," "laziness," "carelessness" or "lack of concern" were ranked among the "top five" of the limitations regarding SWC activities. Reproaches arise with regard to the lack of individual responsibility towards the coming generation, short-term thinking, and selfishness.

While the three most important limitations (off-farm income, lack of incentives and lack of manpower, see above) are all linked to economic considerations, the factor of attitude seems, at the first glance, to add a new dimension. On a closer look, however, it becomes clear that the farmers' individual attitudes are closely linked to the economic issues discussed above. It is therefore necessary – without denying attitude as a limitation for SWC – to examine the reasons behind lacking motivation to invest in SWC:

- Insecure land tenure prevents long-term benefits
- Off-farm employment (land is not the main source of income)
- "Receiver mentality" (based on experience from FFW / CFW campaigns)
- Lack of short-term profitability of SWC interventions
- Expectation of low yields (e.g. in marginal steep areas)
- High maintenance costs and a negative cost-benefit ratio
- Land scarcity (only for measures that occupy cropland, e.g. tied ridges)
- Lack of manpower
- Lack of organisation and mutual help (no collective SWC work on village initiative)
- Lack of knowledge or awareness (in few cases)
- Traditional thinking and reluctance towards (external) innovations

All these factors are treated as separate points in this chapter. While the individual character and perception of a farmer certainly can have an influence on investments in SWC, in the end the question is more about how the numerous factors influencing decisions on such investments are prioritised.

Insecure land use rights (periodical land redistributions)

Within the existing *diessa* land tenure system, user rights **on cropland** are only temporary: the land is usually redistributed randomly after 7 years (see "Land tenure system," page 28). The lack of long-term land use rights discourages farmers from investing in SWC, particularly with regard to measures that do not promise any short-term benefits (e.g. new contour bunds, tree planting) and measures that require high initial labour or other inputs (e.g. stone terraces, gully reclamation). Farmers state that they will lose any inputs invested, as the benefits from these inputs will be transferred to the next owner of the field: "*You cannot harvest the fruit of your own labour; you invest for the sake of other farmers. Your field will be submitted to another farmer at the time when it is in its best condition and giving good yields, and you lose all the inputs you invested. Those who invest lose, and those who don't work win. The system is unfair and makes people lazy."* (local key informant)

Land tenure becomes particularly problematic when fields have to be rented out to other persons in a shared investment / shared benefit arrangement (due to lack of manpower and/or off-farm activities, see above). In these cases, farmers face even more insecurity with regard to their land use rights, as they may lose the field after as little as one year. Correspondingly, investments into SWC are even less appealing to them.

On **grazing land and afforestation areas** the situation is different again, since user rights in these areas are communal. In the absence of individual user rights, nobody feels responsible for SWC activities in these areas. The result is lacking maintenance.

The farmers' experience shows that on individually owned land (*dominale*) or on land with long-term user rights, structures are actually implemented and maintained on individual initiative, and the land is well-conserved. Many farmers (particularly the "hard workers") are of the opinion that even short-term (i.e. 3-year) investments in SWC are profitable and that constant maintenance is absolutely necessary to keep the land in a good condition and maintain productivity – i.e. to ensure yields and improve food security. However, the *diessa* system also has considerable advantages: (1) Field owners who are not able to establish and maintain SWC measures on their fields (single women, widows, old men, poor farmers) can benefit from others' work and inputs, and (2) there are no landless farmers.

Loss of productive area (land shortage)

The study area is characterised by an extreme scarcity of cropland and grazing land. Land holdings are very small (0.8 ha/household) and productivity is low; this combination leads to severe food security problems. Farmers can therefore hardly accept to lose productive **cropland** to SWC measures, particularly on fertile areas. On the other hand, only few measures occupy a substantial area of land. These include tied ridges (in combination with bunds) and bunds with double ditches (were only implemented on experimental plots); temporary or permanent enclosure (e.g. for afforestation) can also mean a loss of (formerly) arable land. For most other measures, farmers do not consider loss of productive area a problem. They assess the benefits of these measures as clearly higher than the loss in production caused by SWC structures occupying arable land, and are aware that they will incur higher production losses if they let degradation continue. "*It is better to have a small area of conserved land rather than a larger area that is degraded."* (Local key informants, 2004)

Grazing land is even scarcer than cropland. The result is inappropriate management practices (see "Grazing practices", page 115).

Photo 25: *Functional tied ridges are a rarity: Most of these measures have disappeared because the loss of productive area they implicate is not acceptable to farmers.*

Lack of collaboration and of collective efforts

Since maintenance of SWC measures is generally considered an individual task, there is usually no need for collaboration. Nonetheless, there are certain cases or situations where concerted manpower is *needed*:

- For rehabilitation of gullies and pipes, which is very labour-intensive and cannot be carried out individually; furthermore, such degradation hotspots can lead to off-site damage, affecting the fields of other land users if not treated early enough.
- For catchment treatment to reduce erosion throughout the catchment, e.g. for dam protection; this is very labour-intensive and benefits the entire community.
- To help weak / old persons.

However, collective work in the perception of the farmers nowadays is strictly related to externally-initiated campaigns and to the provision of incentives. Group work for SWC on a local initiative is virtually non-existent: farmers are not willing to contribute time, labour or small amounts of money (e.g. to purchase stones) for collective work. Initiatives to organise collective gully rehabilitation have failed. The traditional *com* approach (see "Village-initiated approach," page 45) is used for SWC only in very rare cases – e.g. for labour-intensive gully reclamation.

Photo 26: *When the damage reaches such dimensions, collaborative activities are needed. However, this rarely happens within the community and therefore, such cases often remain unsolved or need external inputs.*

One of the reasons for this may be rooted in cultural barriers and individualism. Moreover, collective work is also affected by the above-mentioned lack of manpower: collective work was formerly carried out mainly by the younger (i.e. the active, strong) generation – the generation which is now largely missing.

Absence of collaboration and mutual help is considered a problem especially by the disabled (old or sick farmers) and women who depend on the support of others, given the fact that hiring workers is economically not feasible (costs around 3 US$ per person day).

Lack of knowledge and awareness

Generally, all farmers are aware of existing degradation problems and of the benefits of SWC measures. Knowledge on local measures has been passed down from father to son over generations. Introduced measures, as well, are relatively simple and easy to replicate. Farmers have a good understanding of how to build stable structures from stones – which appears to pose the greatest technical challenge aside from exact contour layout.

Farmers emphasised that their problem is not the required technical knowledge, which they generally have, but rather a lack of awareness of functions, effects and benefits of specific introduced measures due to insufficient communication and knowledge transfer during campaigns. For example, farmers were not informed or instructed about the purpose and benefits of grass strips, nor about the necessary maintenance activities; they were not even involved in the establishment of the strips, which was done by students during a summer campaign. Moreover, many farmers were not aware of the purpose of tied ridges. Some farmers also stated that technical assistance was insufficient during implementation of SWC measures in campaigns, resulting in improper establishment of some of the structures.

Initial training, including clear communication of the purpose and benefits of the measure in question and instructions on the necessary maintenance activities, as well as technical assistance during the establishment phase, are prerequisites for farmers to understand and successfully apply measures that are not yet commonly practised (such as planting of grass strips).

High costs and low availability of inputs

Farmers often do not consider implementation of structures costly in terms of money – at least as long as there is no need for external inputs – since it is basically their own labour they invest. However, lack of financial resources becomes a problem in cases where farmers are, for some reason, not able to work on their field and thus depend on the collaboration of other villagers. If no manpower is available in the family and no help is offered by neighbours (see also “Lack of collaboration” and “Lack of manpower” above), the only way to get the work done is to hire day-labourers; however, farmers can rarely afford their wages of around 3 US$ per day.

The livelihood system is based on subsistence farming and economic resources to purchase external inputs such as agrochemicals, special equipment or seedlings, are lacking. Measures which require such inputs cannot be sustained by the land users without outside support, which in case of artificial fertiliser for example means a major limitation to fertility management. Regarding small land plots and insecure land tenure, the availability of access to inputs to increase productivity would be very important.

Generally local measures face few constraints, since required inputs are mostly available on-farm. An exception is manure, of which there is currently a shortage. (see “The importance of soil fertility management in local soil and water conservation”, page 104). Furthermore, female-headed households and poor farmers partly lack basic farming equipment and draught animals. Shortage of tools / ploughing implements is rarely resolved through mutual support among the villagers (see “Lack of collaboration”).

Low effectiveness of SWC measures

Farmers consider productivity the most important criterion when assessing the effectiveness of SWC measures. Measures that help to increase productivity by 1) reducing surface erosion (and thus reducing loss of applied manure), 2) improving water availability, or 3) improving fertility are generally well-accepted. Nearly all measures cover at least one of these aspects and are thus considered effective. Exceptions include tree planting, where the effectiveness is not directly obvious, and, in part, soil bunds, which are said to be insufficiently stable to resist floods during the rainy season. Moreover, some vegetative measures are said to be prone to damage by drought and overgrazing.

Ecological disadvantages

Ecological disadvantages of SWC measures are generally considered a minor problem compared to their positive effects. However, several measures are said to have a negative effect on overall production and are thus not so well-accepted:

- Soil bunds / tied ridges in flat areas: can cause waterlogging
- Vegetative measures: competition for water, nutrients and light; habitat for birds and rodents (the latter can induce pipe erosion on terraces).

Lack of legislation

Structures implemented through MoA campaigns are under protection; dismantling and modifications are not allowed. However, apart from directives there is no law or legislation in place. There are no legal means to reprimand farmers who neglect maintenance (e.g. punishment, sanctions) or to reward those who maintain their measures well. Once a campaign is over and SWC measures are established, the responsibility is shifted to the villagers, and each farmer is responsible for keeping the measures on his own field in a good condition (expert key informant 2006).

Several farmers mentioned that legal pressure from the outside might help to maintain what has been implemented. Customary laws at village level made by the community might be an even more promising option for promoting SWC activities; they might prove helpful especially in cases where a lack of maintenance causes downstream damage on neighbouring fields, or where concerted action is needed.

The “hard workers” were of the opinion that the problem is not a lack of legislation but the lack of will and commitment on the part of individual farmers.

Grazing practices

Grazing land is extremely scarce in the study area. This shortage leads to the practice of uncontrolled grazing / open grazing on cropland. This practice has negative impacts on SWC:

- Animals (cattle, sheep, goats) graze on agricultural fields and trample on SWC structures, destroying them; this considerably increases the labour input required for the maintenance of SWC measures.
- Growth of a vegetation cover to protect the soil against the impact of splash and runoff, as well as the establishment of vegetative measures (e.g. grass strips) is difficult unless the area is fenced off against grazing animals.

One could also argue that open grazing is part of the local farming system and that SWC measures have to be adapted to it. In any case, it is difficult to change these culturally anchored practices. However, the fact remains that improved grazing land management does have great potential to solve the above-mentioned problems.

Photo 27: *Several problems are associated with the commonly used practice of open grazing. It leads, for instance, to damaged SWC structures (trampling by livestock) and leaves the soil bare of vegetative cover.*

Cultural aspects

Several cultural aspects, albeit not a direct limitation to SWC activities, aggravate the lack of manpower:

- Work restrictions due to religious events and holidays are a constraint on field activities in general and on SWC in particular, since the latter is often perceived as "additional" work not directly linked to production. One fifth of the days of the year are holidays on which field work is not allowed.
- Traditional patterns of labour division between women and men reduce the available work force: women are not supposed to carry out certain types of field work, such as ploughing.
- Other commitments and tasks in the village absorb part of the available work force (see "Lack of manpower" above).

Furthermore, the dependence on support from neighbours is not reputable. Reluctance to innovations (e.g. certain introduced measures) is not culturally founded, but linked to very practical reasons or individual perceptions.

Low productivity of a site / expected yields

Fields on steep slopes with unfertile, shallow soils are low in productivity. In these marginal areas, the benefits of SWC no longer outweigh the costs; investments do not pay. The uncertainty of good yields is additionally increased by the unreliable rainfall pattern. Farming is simply not profitable in these areas. Farmers are forced to focus their limited resources on high potential land and therefore minimise investments in fields where they cannot expect satisfactory yields. Abandonment of SWC measures on poor land results in further degradation, which again reduces productivity: the vicious circle is complete.

Poor accessibility of a site *(external observation by study team)*

Poor accessibility of agricultural plots can be a constraint on SWC, especially with regard to measures that require transportation of material or use of equipment. Fields in marginal and remote areas are often not treated with the same frequency as fields that are easily accessible. It is particularly striking how conservation measures around the settlement area (Gedena zone) are constantly maintained: Here, farmers invest inputs (such as fertiliser) and labour. Through continuous and intensive investment they have succeeded in increasing the productivity and thus the value of this land. This shows that accessibility does have an influence on the quality of the land. However, farmers will always first invest on high-yielding areas, regardless of their accessibility.

Lack of land users' involvement in planning, implementation and evaluation *(external observation by study team)*

One of the main reasons leading to lack of acceptance and failure of introduced SWC measures is that land users are not actively involved in decision-making, both at the planning level and in the field, on questions such as which type of SWC measure is to be applied where. Users' needs are not sufficiently considered, and local knowledge is not included in technology development.

Generally, land users are involved in the application of introduced measures only during the establishment phase, when they are motivated by incentives. The condition and impacts of established measures are not evaluated, leaving the reasons behind lacking maintenance unrevealed. Problems of attitude and awareness are linked to this lack of participation.

Involving land users in SWC projects from the very beginning is a prerequisite for creating a feeling of ownership and responsibility among them. Increased knowledge and understanding will also increase the degree of integration and adaptation of SWC measures.

Local and external perception of limitations of SWC

The problems described above relate to both establishment and maintenance of SWC measures. However, since the area has a quantitatively high coverage of SWC measures, the focus has to be on maintenance of existing measures. Maintenance has shown to be most problematic:

- in case of highly labour-intensive measures;
- on land other than cropland (communal land);
- on marginal land (fertility, accessibility of land).

Table 20 summarises the limitations of SWC activities – as assessed by farmers and researchers – and specifies which measures are mainly affected (by each factor). Figure 5 visualises the differences between the local (farmers) and the external (study team) perception.

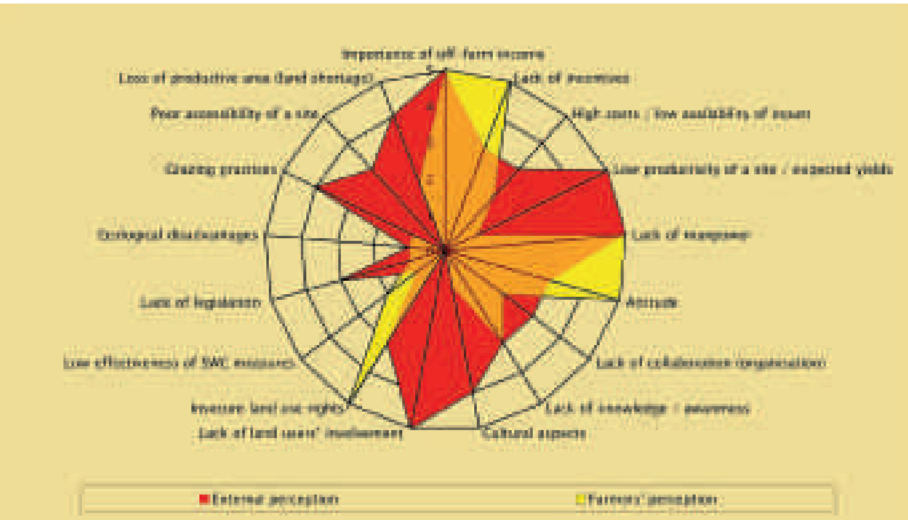


Figure 5: *Local and external perception of limitations of SWC*

1 = low impact
2 = low – moderate impact
3 = moderate impact
4 = moderate – high impact
5 = high impact

Table 20: Local and external perception of limitations of SWC

Aspect	Farmers' perception	External perception	Measures / activities concerned
Importance of off-farm income	XXX	XXX	Agricultural activities in general, including SWC measures
Lack of incentives	XXX	XX	Structural measures (e.g. terraces, stone and earth bunds, tied ridges, check dams)
Lack of manpower	XXX	XXX	Structural measures (e.g. traditional stone terraces, check dams, stone and earth bunds); application of compost / manure (if requiring transport)
Attitude	XXX	XX	All SWC measures; particularly introduced measures
Insecure land use rights	XXX	XX	Measures with mid- or long-term benefits (e.g. new contour bunds, tree planting) and/or measures requiring high initial inputs (labour, other; e.g. stone terraces, gully reclamation); generally measures applied on communal land (e.g. afforestation area)
Loss of productive area (land shortage)	X(X)	XX(X)	Tied ridges; enclosure for afforestation (permanent loss of arable land); fallowing (temporary enclosure); *fanya juu* / double ditch; traditional stone terrace (high risers)
Lack of collaboration	X(X)	XX	Structural measures (terraces, bunds, tied ridges, check dams) that require high labour input
Lack of knowledge / awareness	XX	XX	Grass strips, tied ridges; introduced measures in general
High costs / low availability of inputs	X(X)	XX	Application of fertiliser / compost (shortage of manure); local ploughing system (lack of ploughing tools, need to rent oxen); seedlings and seeds for grass strips and tree plantation (partly available for free from MoA plant nurseries); levelling instruments for measures laid out along the contour (e.g. stone / earth bunds; tools are provided during campaigns)
Low effectiveness of SWC measures	X(X)	X	Soil bunds (low durability, not resistant to high runoff); tree planting on cropland; tied ridges; stone mulching; grass strips (on bunds); micro-basins (for tree plantation); live barriers / fences (*sisal*); stone bunds not combined with soil (low potential to conserve water); vegetative measures (low durability, affected by drought and overgrazing)
Ecological disadvantages	X	X	Tied ridges / soil bunds in flat areas (waterlogging), trees / shrubs on cropland (competition with crops for water / nutrients / light; habitat for birds that eat seeds and rodents that induce pipe erosion); stone mulching (limits growth of certain crops such as onions, potatoes)
Lack of legislation	X	XX	Structural measures in general (with regard to maintenance)
Grazing practices	X	XX(X)	Grass strips; structural measures on cropland (stone and earth bunds); manure application
Cultural aspects	X	XX(X)	Mainly introduced measures (not integrated in farming system); measures requiring a high labour input (restricted working time due to religious holidays); water drainage (conflicts); vegetative measures ("trees are bad")
Low productivity of a site / expected yields	X	XXX	Structural measures (such as contour bunds, terraces) that require annual maintenance; site specific application of manure and fertiliser
Poor accessibility of a site	-	XX	SWC activities in general; steep, marginal land situated far from the village is often in a poor condition (whereas the steep slopes close to the settlements are nicely conserved). This problem is linked to productivity.
Lack of land users' involvement	-	XXX	Generally new (introduced) measures

XXX = high impact on acceptance of SWC measures
XX = moderate impact on acceptance of SWC measures
X = low (but still significant) impact on acceptance of SWC measures
\- = not ranked by farmers
Farmers' perception: The top five aspects were evaluated in a PRA, other aspects were rated on the basis of individual interviews.
External perception: Ranking done by the study team.

Acceptance, area coverage and condition: comparison between different SWC measures

In this section, the ratings given by the farmers with regard to acceptance, area coverage and condition of SWC measures (see pages 52 et sqq.) are compared and interpreted within the categories of structural, vegetative and agronomic measures. More analysis on these SWC categories and measures – based on the geographical information system – are presented in the map section of the synthesis of this report (see pages 150 et sqq.).

Agronomic measures

Agronomic measures generally have a high level of acceptance. Most are traditional, have been practised for generations and are thus well-integrated or even part of everyday farming activities. Their main purpose is directly linked to sustaining / increasing productivity (short-term effect on yields), which is a crucial aspect in a self-sustaining economy. Application of chemical fertiliser is limited because farmers cannot afford to buy it in desired quantities. Stone mulching clearly has a lower acceptance: this measure is not considered a SWC measure by many farmers, though they clearly recognise the benefits of it; rather they see it as a natural condition. Correlation between acceptance and area coverage is quite good. Condition was not evaluated, since these measures are repeated seasonally and thus do not need maintenance.

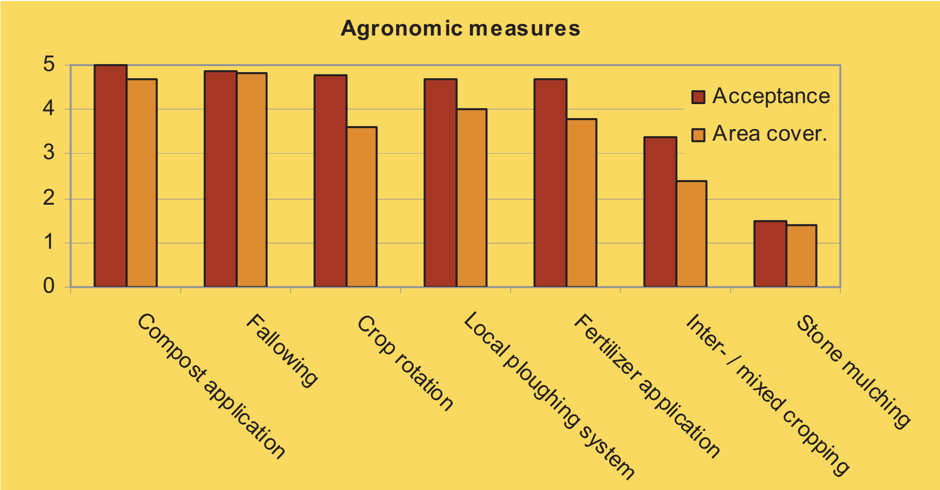


***Figure 6:** Acceptance and area coverage of agronomic measures.*

Vegetative measures

Vegetative measures on cropland are almost inexistent in the study area. This is also reflected in the rankings of grass strips, live barriers and trees on cropland, which are among the lowest of all SWC measures. Reasons are manifold: livestock management (open grazing practices), semi-arid climate (with an extended dry period), lack of information (training), vegetation as a habitat for undesired animals, competition with crops for water, nutrients, and light; lack of short-term benefits. Vegetative measures are primarily introduced. There is only one vegetative measure that is well-accepted: local enclosure (preservation / regeneration of natural vegetation). However, while the acceptance of this measure is high, area cover is rather low, one of the main reasons being the serious land shortage: land is needed for crop production.

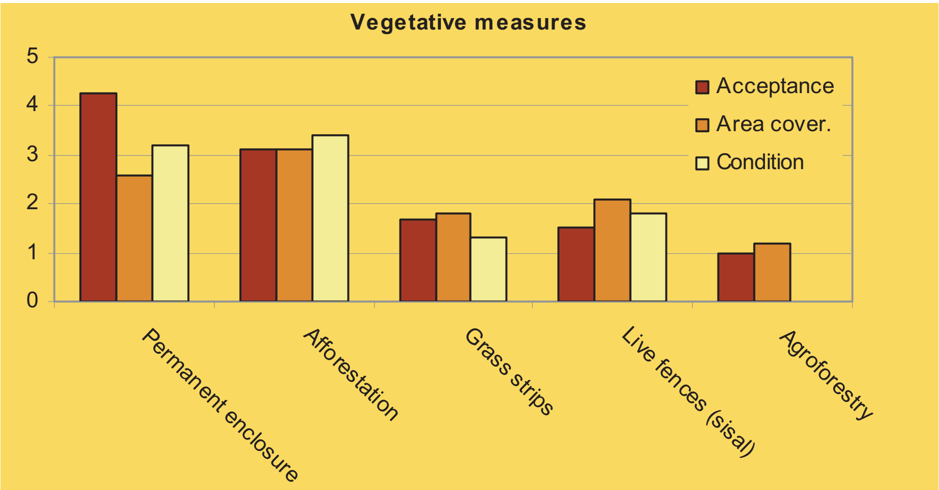


***Figure 7:** Acceptance, area coverage and condition of vegetative measures.*

Structural measures

Generally, the chart shows a nice correlation between acceptance and area coverage, while condition (maintenance) is relatively low for the "top 4" – which reflects the general impression of the farmers: in terms of quantity there are enough SWC measures implemented, but maintenance is insufficient. However, we have to be aware that the chart only shows average ranks and that there is a high spatial variability (see Map 4, page 154, and Map 5, page 156) with a concentration of investments on high potential areas.

The traditional stone terrace appears to be the best accepted practice among the structural measures, followed by the introduced stone (and earth) bunds, which actually has the highest acceptance rate of all introduced SWC measures: replication rate is high, farmers are convinced by the benefits, and they have well-integrated the structures into their land management system. Significantly below the average in terms of acceptance are:

- Earth bunds: In the PRA exercise the farmers differentiated 3 types of introduced contour bunds: stone and earth bunds, stone bunds, and earth bunds; the latter are clearly less accepted and less widespread, due to low durability (do not resist high runoff and risk of waterlogging). In contrast, the locally developed boundary earth bunds are well-accepted.
- Micro-basins: these structures are only applied on communal land (for tree planting); the absence of individual land use rights results in lack of responsibility and poor motivation to maintain the micro-basins.
- Tied ridges: a measure that occupies land where productivity is highest: directly behind the bunds. Facing serious land shortage, the benefits of this measure are not high enough and acceptance is extremely low.

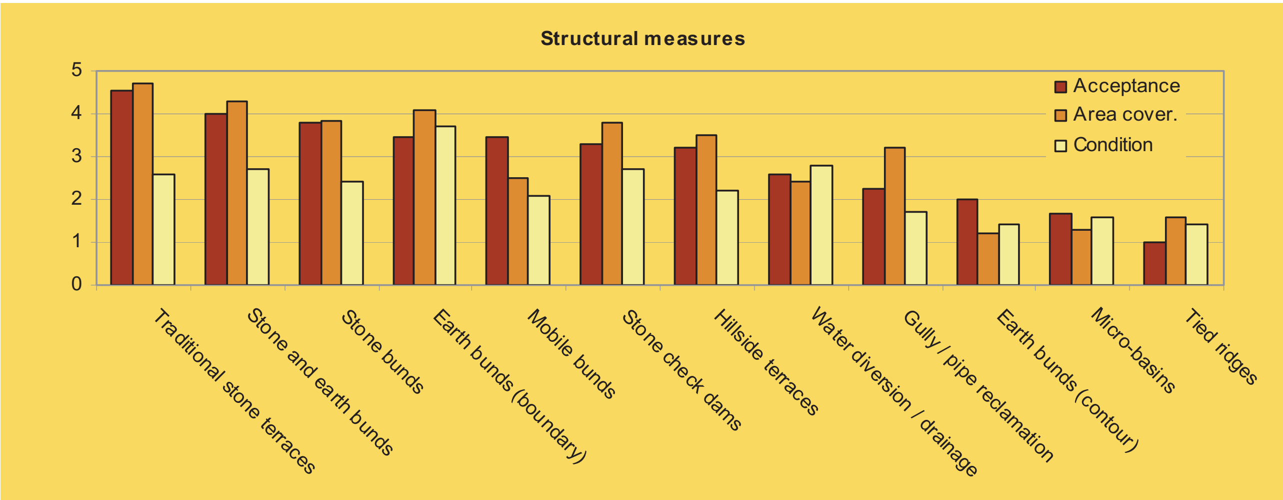


Figure 8: Acceptance, area coverage and condition of structural measures

Note: Area coverage and spatial distribution of SWC measures are illustrated in maps 2-5 on pages 152 et sqq.

Accumulated soil at the bottom of a small, dried out dam in Afdeyu. The siltation of dams indicates how much soil is lost from farmers' fields. Part 3 provides an analysis of the soil: Soil types and fertility classes are assessed based on local knowledge. In a second step, the local soil classification is compared to scientific study results (Photo 28).

Local and scientific soil classification

Local soil classification

Scientific soil analysis and soil classification

Comparison of study results with secondary data from other surveys

Local soil classification

Introduction

A local soil classification is a categorisation of soil resources into different soil types based on local knowledge. Local knowledge, also referred to as ethnoscience or traditional, indigenous, folk, or native knowledge, can be defined, relative to agriculture in its broadest sense, as the accumulated knowledge, skills and technology of local people derived from their direct interaction with the environment (Altieri 1990, in Ettema 1994). Information is passed on from generation to generation and refined into a system of understanding of natural resources and relevant ecological processes (Pawluk et al 1992, in Ettema 1994). In comparison to scientific classification systems, local classification systems are normally difficult to compare on a larger scale since they are based on local criteria and languages and are influenced by specific local needs for certain crops.

The value (and also the goal) of this inventory is to provide a fast and easy assessment tool at a local to regional level and to provide a commonly understandable language for all stakeholders.

Advantages of local soil classification systems

Assessments based on local soil classifications…

- are faster and cheaper compared to scientific soil surveys;
- can offer better insights into local criteria and perceptions of soils in relation to agricultural production, and thus help to better understand actions and reactions of farmers on problems occurring in the context of soil management;
- can considerably facilitate communication between local land users and external specialists, such as extensionists, development workers and researchers; a common understanding and a common language base are essential for:
  - discussions about (local) soil properties and problems, about agricultural management, or when offering trainings or introductions of new technologies;
  - multi-level and multi-stakeholder approaches, when farmers join discussions and help to design project proposals;
- are basically application-oriented, while scientific classification systems are based on knowledge about pedogenesis and chemical and physical soil properties, which makes their application in the field difficult.

(based on Niemeijer 1995 and Ettema 1994)

Limitations of local soil classification systems

Local soil classifications…

- are mainly based on properties of the topsoil horizon, which makes it difficult to draw conclusions regarding the deeper layers and the parent material;
- are often inconsistent throughout time and space: different soil properties might be referred to with the same name in different areas, and similar properties might be called differently in different locations; the meaning of a local name can change over time, as soil characteristics themselves change;
- often do not offer adequate tools for an exact delineation of soil type boundaries by the farmers, since local concepts consider changes in soil properties to be continuous;
- are based on a small selection of production-related soil properties such as soil depth, rooting depth, topsoil structure and texture, fertility, water holding capacity, etc.; certain factors connected with low yields, such as inappropriate soil management practices, can therefore easily be hidden behind a "wrong" classification;
- are based on a different concept and other criteria than scientific classifications (see "Comparing local and scientific soil types" below); this complicates comparison between the two.

(based on Niemeijer 1995 and Ettema 1994)

The above-mentioned limitations often make it difficult to base planning of development activities only on local soil classifications.

In order to minimise the problems of spatial inconsistencies, the study was restricted to one agro-ecological zone and to farmers with the same ethno-linguistic background. In a preliminary step, the key informants of the villages within the research perimeter discussed the terminology to make sure that the assessment was based on the same concept and a common understanding in all villages.

Photo 29*: Assessing soil types and fertility status in the field: Farmers from different villages were the key informants for the participatory mapping and for the local soil classification.*

Comparing local and scientific soil types:

Distinctions made by indigenous communities have been proved in many cases to be scientifically valid and statistically testable (Ettema 1994). However, local classifications are often based on other premises than scientific classifications, which may complicate comparison and correlation between the two (Niemeijer 1995).

Table 21*: Differences between scientific and local soil classifications*

Scientific classifications...	Local classifications...
tend to focus also on the deeper soil horizons	focus on the surface horizons (most relevant in agriculture)
strive for universal applicability	are usually site- and application-specific
often make use of pedogenetic criteria for their semantic organisation (nomenclature)	often have a semantic structure that represents the land-use interests of the community
are concerned primarily with invariant soil characteristics that make it possible to assign a soil unambiguously to a single class	are concerned with direct evaluative characteristics, which are affected by land use; classification based on qualitative characteristics.

The above differences imply that soil maps based on local knowledge are to some extent dynamic, i.e. that the classification of certain land units will change over time, and thus that they cannot be dealt with in the same way as static scientific soil maps. (Source: Niemeijer 1995)

Local soil typology

Based on their long-term agricultural experience and continuous interaction with the soil, farmers have a detailed knowledge of the local soil characteristics, of soil-related management problems, and of the suitability of the different soil types for different crops.

To classify their soils, farmers use criteria that are easy to understand and visible in the field, be it directly or indirectly, e.g. via crop growth and crop performance.

Soil classification criteria

The main classification criteria used by the farmers in the study area were:

- soil colour
- crop yield / crop performance
- water holding capacity (infiltration, period of water availability)
- soil texture / soil structure (consistence)

Further important criteria were:

- stoniness, gravel content
- soil depth
- slope and exposition
- soil erodibility
- soil workability
- soil suitability for different crops
- quality for other uses (different from agriculture)

Based on the soil properties mentioned above, during long group discussions the local key informants defined three major soil types: *Duka*, white soil and red soil. A fourth type, which was initially not mentioned, proved necessary to be distinguished as a separate category during soil mapping. In the following section, the major soil types and their properties are described in detail based on farmers' perceptions.

Major soil types:

- *Duka*
- Red soil – *Keih hamed*
- White soil – *Tsa'eda hamed*

Additional soil type:

- shallow, rocky soil; rocky outcrops

For spatial distribution of soil types see Map 7 on page 160.

Duka soil

The term *duka* does not have any specific meaning and cannot be translated. Sometimes it is also called *reguid hamed* (thick soil) or *shiebet* (fertile, flat land), but these names refer rather to the fertility status (see "Soil fertility classification", page 133) than to the soil type. *Duka* is the predominant soil type in the study area, covering about 54% of the total surveyed area (574 ha). It is found in various different topographic units ranging from flat slopes to undulating and hilly slopes in afforested areas.

Duka is of brownish colour, ranging from light to dark brown, and is definitely the darkest soil in the area. *Duka* has a higher clay content than the other two important soil types found in the area. Its texture is fine, making the soil very cohesive. *Duka* usually forms solid clods. Sometimes cracking occurs. Under dry conditions, *duka* is comparatively hard, and the clods are hard to break. When wet, it becomes slippery and slightly elastic, allowing for long rolls to be formed (longer than with the other major soil types). Quandoba farmers specify information for different soil horizons: A is soft, B is medium, and C is hard. In flat areas, dark, buried clay horizons can be found. *Duka* is the deepest soil in the area: According to farmers soil depth of *duka* is often more than 1 m (on hillsides) and can reach up to 4 m and more in flat areas.

Infiltration rates are low and drainage is generally poor. This makes *duka* soil susceptible to waterlogging, which can affect plant growth. In areas where waterlogging is a serious problem, most farmers construct drainage ditches and field border outlets to drain excess water from their fields (see "Water diversion and drainage system", page 59). Infiltration can be improved considerably by means of adequate land management practices, especially ploughing. Generally, *duka* has a high water holding capacity. The fine texture of *duka* reduces evaporation, but is at the same time responsible for the soil's high adhesiveness, which leads to a great amount of water being fixed in the micro-pores. As a result, the water is unavailable to plants, causing fast wilting in dry conditions.

Duka is not susceptible to erosion, except when it is exposed to heavy rainfall or inappropriate land management (ploughing along the slope). Gullies occur only in areas affected by concentrated runoff or floods. Apart from this information collected from farmers, the study team noticed that gullies in *duka* are deeper than those occurring in other soil types. Furthermore, pipe erosion (tunnel erosion) in *duka* soil was observed in several instances on terraces. The workability of *duka* is poor both when dry (hard) or when too wet (muddy). Land preparation activities are therefore restricted to periods of optimal conditions following rainfalls.

Photo 30: *Duka is the most common soil and, at the same time, it is suitable for a wide range of crops. Yields are especially high in flat areas. Workability tends to be poor, though.*

Duka is the most fertile soil type in the area, providing constant high yields for a wide variety of crops and trees as long as there is enough water available for plant growth. The fertility of *duka* depends on the slope angle: the flatter the area, the more fertile the soil.

In this study, the performance of wheat served as a reference for comparing soil fertility among the different soil types (see Table 22, page 128). One grain of wheat sown in *duka* can grow into a plant of up to 75–100 cm and has a tillering capacity of about 20, each panicle producing 80–100 grains. However, wheat grows very fast when water availability is high, resulting in weak stems and a high risk of undesirable crop lodging. Therefore, farmers prefer to grow barley on *duka* soil. Other crops grown on *duka* include potato, horse bean, maize, and various vegetables, such as onion, tomato, and carrots.

Fertility indicator plants such as *oxygonum sinuatum* (locally: *chew mrakut*) and *xanthium spinosum* (*eshok mergem*) are common on *duka* soils. *Duka* generally has the highest plant diversity among the soil types of the area. Other plants often associated with *duka* include: *Acacia abyssinica* (local name: *cheia-fentera*), *Phytolacca dodecandra* (*shibti*), and two species of which the Latin name could not be identified: *baelalito* and *tehaloeito*; in former times also juniper (*tshdi*), *Olea africana* (*awlie*) and *Dodonaea angustifolia* (*tahses*) grew on *duka*. Pests such as white grub (*Phyllophaga* spp., locally: *kubi*) may occur in fertile plains with periodical waterlogging. Gravel content of *duka* varies from "very stony" (= *duka regah*) to "no stones at all." Fields with a high gravel content are called *regah* and are quite common in *duka*. A high gravel content not only improves water availability by preventing evaporation from the soil surface, but also protects the soil against erosion.

Red soil – *keih hamed*

Keih hamed is Tigrinya for "red soil." Very rarely it is also called *keih meriet*, which means "red land." Red soils are most often found on steep undulating slopes and on gentle slopes. They cover 14% of the study area. The colour of *keih hamed* is red to reddish brown. Due to its fine texture (loamy sand) and loose structure, farmers often refer to it as "soft, fine soil." When mixed with water, *keih hamed* soils develop plastic characteristics; when drying out, they do not crack or form clods. If red soils occur in combination with *tsetser*, the texture tends to be more sandy. Soil depth varies from very shallow (about 20 cm) to very deep (over 2 m).

Photo 31: *A typical example of the less wide-spread red soil. The soil colour is a major classification criterion in local soil classification.*

The water holding capacity of *keih hamed* is good if the soil is sufficiently deep, keeping crops from wilting all too fast after the end of the rains. Infiltration rates are high, and waterlogging occurs only on terraces over short periods after heavy rainfall events. On steep slopes with limited rooting depth, the water-holding capacity is smaller. Infiltration can be reduced considerably through the development of hardpans and crusting, which occurs particularly where red soils are combined with *tsetser*.

Soil fertility expressed in terms of yields is low, and crop growth is rather slow. One grain of wheat can produce 30–50 grains per spike; the plants grow to a height of 50–60 cm when mature. Crops sown in *keih hamed* produce few tillers. Farmers prefer to grow linseed or wheat on red soils. Under application of fertiliser (manure), barley and beans can be grown as well. In contrast to white soils, *keih hamed* soils respond positively to fertiliser (manure) according to farmers from Quandoba and Adi Jin. Transitions of red to white soil are less fertile than typical red soil.

Indicator plants on red soils include *Rumex usambarensis* (local name: *hihot*, grows in mountainous areas), *Meriandra bengalensis* (*nihba*), and *Steganotaenia araliacea* (*enderguhla*), all of them deep rooted trees that remain green all year round and are known as indicators for shallow, rocky soils with low soil fertility. In afforestation areas, sugar gum (*keih kelamitos*) is well-adapted to the conditions and grows best on red soil.

Red soils are less susceptible to surface erosion and gully formation than white soils. Erosion rates are nevertheless high, especially on steep slopes, but also on gentle slopes without conservation measures. Farmers consider *keih hamed* soil to have a relatively good workability even when dry, with the exception of areas where it occurs in association with *tsetser* (see page 129) and hardpans. Ploughing is difficult after rainfalls when the soil tends to become muddy, but also when it is very dry. Red soil is commonly used for roofing traditional houses (*hidmo*); when compacted, this soil material is almost waterproof.

Keih hamed is often covered by *tsetser*. This gravel layer changes the soil properties to such a degree that farmers classify these soils as a sub-type called *keih tsetser.* For specifications of *keih tsetser* see below.

White soil – *tsa'eda hamed*

Tsa'eda hamed means white soil. Synonyms for *tsa'eda hamed* are *fahshaw* (meaning greyish) and *hamukshtay* (meaning ashy). This type of soil covers 26% of the study area and is found on gentle slopes and in areas with an undulating topography. It has a characteristic bright colour, varying between white, greyish and a light sandy colour (beige). Farmers describe the texture as "soft." *Tsa'eda hamed* soils are generally characterised by a very powdery structure and a very low cohesiveness, and do not form clods or cracks. Soil workability is good both in dry and in wet conditions (no muddiness).

White soils are often shallow on hillsides and slightly deeper in plains, especially in the lower southern part of Quandoba*.* There is no stone barrier in lower soil horizons: the transition to parent material is hardly visible. That's why farmers in Adi Jin characterise white soils as deep.

While infiltration rates in *tsa'eda hamed* are typically high (the soil gets wet easily even from small amounts of rain); its water holding capacity is very low (the lowest of the three main soil types) due to high drainage and evaporation rates; soil moisture is usually lost soon after the rain stops. During periods of low rainfalls, *tsa'eda hamed* dries out quickly, causing crops to wilt.

The fertility of *tsa'eda hamed* is low; it is considered the poorest soil type in the area. Yields are only moderate even when enough water is available and soil management is adequate. The soil's response to manure is limited because decomposition of the manure is insufficient, especially under dry conditions. One spike of wheat sown in *tsa'eda hamed* produces 10–20 grains, and panicles have a maximum stem length of 30–40 cm when fully grown. Farmers in Quandoba distinguish two sub-types of white soil: greyish soil is more fertile than whitish soil.

Farmers produce mainly wheat and linseed on white soils. Other crops perform poorly unless enough water is available and manure is applied – which is usually done in the first cropping season after fallowing. Under optimal conditions (sufficient water availability and proper soil management) barley can be grown as well. In afforestation areas, *tsa'eda hamed* soils are mostly planted with acacia and sugar gum (*keih kelamitos*). *Meriandra bengalensis* (*nihba* tree) and a local grass species (*meker sa'eri*) are the main species growing on white soils. Both plants are indicators of low soil fertility.

Erodibility of *tsa'eda hamed* is very high. Compared with the other major soil types, white soils are most susceptible to erosion, with rills and gullies developing even from low-intensity rainfall. Eroded material from white soils is often transported into lower, flatter areas, where it forms alluvial deposits (*tswar hamed*).

Photo 32: *In white soils, the transition between the soil and the parent material is not clear. White soils comparatively have the lowest soil fertility and water storage capacity.*

Generally, white soils have a low gravel content. Sometimes they are associated with white quartz gravel (*tsetser*), which, according to farmers' statements, change its soil properties as follows:

The water holding capacity increases, which has a positive impact on "soil fertility" (less wilting of crops at the end of rainy season). White soil with *tsetser* is hard to plough and less affected by erosion.

Rocky soil / rocky outcrops

This category describes uncultivated shallow rocky soils and rock outcrops. Considering the area it covers (6%), this soil type cannot be neglected in the present classification. However, farmers did not mention it; since it has no potential for crop production, they do not include it their classification. In their perception it is just the "remaining area," often full of rocks or covered by a very thin, unfertile and stony soil layer.

Table 22: Properties of the three major soil types

Properties	*Duka*	Red soil – *keih hamed*	White soil – *tsa'eda hamed*
Other name(s)	*Reguid hamed* (high fertility *duka* in flat areas); *shiebet*;	*Keih meriet*; subtype: *keih tsetser*	*Hamukshtay*; *fahshaw*
Area coverage	54%	14%	26%
Colour	Light to dark brown	Red, reddish	Ashy, whitish, sandy colour (beige)
Texture	Very cohesive, fine; clay content is higher in the lower soil horizons; some cracking	Fine; plastic when wet; no cracks	No cohesion, very fine and soft
Consistence, structure	Soft; muddy / slippery and cohesive when wet; fragile and friable when dry; forms clods	Loose, no clods	No stable clods; powdery when dry
Gravel content, stoniness	Partly very stony; partly no stones at all	Often covered by *tsetser* gravel	Generally few stones; partly moderate stoniness
Depth	Deep; 1 m up to > 4 m	Shallow to deep (few cm up to > 2 m); no stone barrier at bottom of profile	Frequently shallow; no stone barrier at bottom of profile
Water holding capacity	Good; slow drying after rain	Good; cereals do not wilt for a long time even when rainfall is scarce	Very poor; fast drying after rain
Drainage / infiltration	Poor to moderate; waterlogging in flat areas; low infiltration rate	Poor to moderate; very low when hardpans occur (especially with *tsetser*)	Good; high infiltration rate
Fertility based on the performance of wheat	Fertile; high tillering capacity (up to 20); 80–100 grains/panicle	Moderate; low tillering capacity; 30–50 grains/panicle; high response to manuring	Poor; no tillering; 10–20 grains/panicle; poor response to manuring
Indicator plants	High diversity; *oxygonum sinuatum*, *xanthium spino-sum* (fertility indicator plants)	*Meriandra bengalensis*, *steganotaenia* spp.	Very limited diversity; *meker sa'eri* (grass, botanical name not identified)
Slope, topo-graphic position	Fertile *duka*: flat land; poor / medium *duka*: sloping land	Frequent on hillsides; moderate to hilly topography	Frequent on hillsides
Susceptibility to erosion	Low	High	Very high
Soil workability	Difficult to plough, hard when dry, muddy when wet	Good to moderate; hard with *tsetser*	Good
Major limitations	Workability	Hardpan formation, specially with *tsetser*	Poor fertility; poor water holding capacity; poor response to manure
Suitability for different crops	Suitable for all crops, mainly used for barley; also potato, horse bean, maize, vegetables	Linseed and wheat; if fertilised also barley and chickpeas; eucalyptus	Mainly wheat; if fertilised also barley; linseed

Variability of properties: sub-classes of soil types

Certain properties are more or less homogeneous within a soil type and can thus be regarded as typical characteristics, such as soil colour and soil texture / structure / consistence. Other properties, such as soil fertility and gravel content, can vary considerably within a single soil type: These properties divide soil types into different "sub-classes" and the corresponding attributes (values) were recorded for each mapping unit in order to further specify the soil type: Map 7 (page 160) is on soil fertility whereas gravel content appears only as an attribute in the Geographical Information System (no map included in this report). Fertility classes are further explained on page 133. Gravel content comprises three classes (for each soil type):

- no / very low gravel content
- *tsetser*: high content of small-sized gravel
- *regah*: high content of medium to big sized stones (5–30 cm)

Some of the fertility or stoniness sub-classes were initially mentioned as independent soil types, but later – during field work and further discussions – turned out to be fertility classes or categories of stoniness rather than separate soil types. Some important examples are:

- *Keih tsetser*: red soils with a high content of white gravel
- *Duka regah*: *duka* with a high content of coarse gravels
- *Duka bodu*: dark *duka;* uncultivated, virgin soil
- *Reguid hamed*: fertile, relatively deep soils with high water storage capacity; often used as a synonym for "fertile *duka*" (see also "Soil fertility classification," page 133).

Keih tsetser

Tsetser is the expression used for small-sized gravel. It is often related to white gravels occurring in the form of unconsolidated, coarsely fractured quartz fragments on agricultural fields. During ploughing, the quartz is broken into small-sized gravel and mixed with the soil. *Tsetser* covers occurs on 30% of the agricultural land in the study area, but the density of the ground cover varies greatly. Even though a dense stone cover reduces the area suitable for crop growing, it also protects the topsoil from erosion and increases soil moisture by reducing evaporation, which – according to the local key informants – raises the fertility status of the soil. *Tsetser* occurs on all major soil types in the area, but is typically associated with *Keih hamed* (62% of *keih hamed* is covered by *tsetser*).

The main crop grown on *keih tsetser* is wheat, but under proper land management and application of manure other crops like barley and beans also perform well. Response to manuring is good (high yields). Wheat reaches a height of 50–90 cm and the seed quality / size is excellent. The required seeding rate is higher than on *duka* due to lower tillering capacity.

Drainage and infiltration rates are reduced by *tsetser* gravel, especially where development of hardpans occurs. Hardpans are formed mainly during the dry season and complicate the soil management, especially when the soil is dry. Indicator plants are *oxygonum atriplicifolium* (*chew mrakut*); in afforestation areas also *Eucalyptus globules* (local name: *tsaeda kelamitos)*, an indicator for high water availability). Erodibility is rather high, especially after tillage. Selective transport of fine soil particles leads to an accumulation of white gravel at the surface, making the soil less susceptible to further erosion.

Duka regah

Regah is the local name for a field covered with small to medium-sized stones (diameter up to 20 cm) mostly of basaltic origin. According to the farmers, *regah* fields are more productive than fields without *regah*, because the stones act as a natural mulch and considerably reduce water loss through evaporation. Farmers have observed that the stones keep the soil moist, a factor that they consider important for the determination of productivity. For obvious reasons, *regah* land is not suitable for tuber crops such as potatoes or onions. *Regah* areas are thus mostly used for barley, beans, wheat, or maize. *Regah* soil can never be cleared from stones, because any removed stones are quickly replaced by surfacing stones from the underlying soil layers that are brought to the top through ploughing and erosion. *Duka regah* has the following properties:

Duka bodu

Duka bodu is also called "dark" *duka* (based on its dark brown colour) or "real" *duka*. It is found on formerly uncultivated virgin soil/land (which is the literal translation of *bodu*), mostly in the mountains and in enclosed forest areas in Afdeyu (Grat Hamushte, Metsan'i). Soil depth is about 3 m; the soil profile shows an alteration between soil and rock layers. The soil structure is loose and is locally called "mouse dung structure." *Duka bodu* has a fragile consistence and disintegrates rapidly. No development of cracks when dry, and no muddiness when wet. No waterlogging due to the loose structure and related high drainage rates.

Good workability is good in all conditions. If there is enough water, *duka bodu* soils are of high fertility and all types of crops grow well; under dry conditions, plants wilt quickly. Farmers therefore prefer crops with a short growing period, especially barley.

Photo 33: *The dark-coloured and fertile duka bodu with its characteristic granular structure is found on virgin land only.*

Local soil types of subordinate importance in the area

Walaka (vertisol, black soil, *tselim hamed, lin*)

These black-coloured clay soils are deep and free of stones. The clay material is used for the local production of pots and ovens. *Walaka* occurs exclusively in plains. It has a high water holding capacity, but a low infiltration rate; therefore, waterlogging persists over several days if the water is not drained. Erodibility is low and soil workability is difficult. When dry, the soil becomes very hard forms large cracks; when wet, it becomes muddy and sticky. Application of manure softens the soil and reduces the problem of muddiness in wet conditions. *Walaka* soils are very fertile. In the study area it is only found in the form of buried horizons (subsoil) in association with *duka*. When properly ploughed (sufficient aeration), fertility is higher than on *duka*; however, *walaka* soils require a higher work input (effort) than *duka*. The crop preferentially grown on *walaka* is wheat, because it is tolerant to wet conditions. Pests such as white grub (*Phyllophaga* spp., locally: *kubi*; a white worm with a black head) occur in black soils. *Phyllophaga* affects seeds and thrive in waterlogged soils. Pests on *walaka* often affect barley; potato and maize do not perform well on *walaka*.

Yellow soil

This soil type of yellowish colour was identified by the farmers in *Sinihabera*, but could not be classified. It occurs between rocky outcrops. It has a high infiltration rate, a high drainage capacity and a very low water holding capacity. The texture is fine and the consistence is muddy when wet. High erodibility and very low soil fertility make yellow soils unattractive for crop growing. Yellow soils are used for wheat and barley production, but the yield is poor: plants reach a maximum height of only 20–50 cm and develop as few as 7–10 grains per seed.

Tswar hamed

This soil type occurs on alluvial plains, in the valley bottom; it is mainly used as grazing land. *Tswar hamed* contains deposited material that has been eroded in upstream areas, often from white soils (as these are highly erodible).

Saline soil

Found only on one small site in the Gedena zone of Afdeyu, on *duka* land (local identification of salinity by tasting).

Shiebet

Shiebet has been mentioned by other authors (Semere Zaid 2002 and TOKER 1996), but could not be identified in the field. According to the farmers, it is not a soil type, but a general expression to describe fertile land in flat areas with high water availability (see also page 133). These areas usually have deep and fertile soils and are intensively used (manure application) and conserved.

Ba'akel

Ba'akel is also mentioned as a local soil type in other publications. It is approached in various ways by farmers, leading to controversial information (see below); possibly it is a subsoil. Sometimes it was also mentioned as a separate soil type with a poor soil fertility, a high sand content, and a low water retention capacity. Farmers of the area mentioned this type of soil in the beginning; however, it could not be found during the field study. Only on a very small spot outside the study area (in New Serejeka), farmers addressed a subsoil as *ba'akel*. A collection of farmers' statements and the team's observations on this soil type are listed below:

- Brighter than *duka*, darker than white soil
- Fertility status largely identical with that of *duka*.
- Reddish, sometimes mentioned instead of *keih hamed*; a mixture of greyish and red soil.
- Very hard when dry; good for roofing (will not allow weeds to grow on the roof of traditional houses (*hidmo*)
- Sometimes the term *ba'akel* is used instead of *duka*.
- Something between stone and soil; "you find this type in lower horizons of red soil"; on easily decomposable rocks.
- Texture: sandy / silt sand (TOKER 1996; Semere Zaid 2002).
- *Ba'akel* is light coloured; low fertility, sandy texture.
- In the "Soil and Water Conservation Manual for Eritrea" (RELMA 2002) luvisol – as one of Eritrea's dominant soil types – is translated to Tigrinya as *ba'akel / duka*. This gives rise to the assumption that the two soil types are related or even identical.

Other

Other soil types, such as white lime soils, dark red soils and yellow soils occur only in very few instances or only in subsoils. They are not used for agriculture, but for painting (of traditional houses or *hidmo*).

Local soil fertility classification

Definition of soil fertility

From the scientific point of view, the term **soil fertility** refers to the inherent capacity of a soil to supply plants with suitable quantities of mineral nutrients (e.g. nitrogen, phosphorus) and organic components (organic matter). The term is related, but not synonymous to **soil productivity**, which refers to the ability of a soil to yield economic products (crops): soil fertility is only one of a number of factors that determine the magnitude of crop yields, i.e. soil productivity (Brady 1990). In contrast with the scientific terminology, farmers define soil fertility based on crop performance and yields.

Photo 34: *Crop yield is a major indicator for soil fertility. Yields depend on the soil type, water availability, manure application and a number of other factors.*

The characteristic fertility classes attributed to each of the main soil types are a generalisation based on a mean value, e.g. *duka* tends to be fertile and white soil rather poor (see description of soil types, pages 124–128). During soil mapping it became clear that fertility can vary greatly within a soil type. This might be related to the fact that soil fertility, in the farmers' understanding, is not limited to the nutrient status but includes many other factors potentially affecting plant growth. The most important of these are discussed below.

Components of soil fertility for local classification

- Water holding capacity / water availability
- Soil depth
- Crop suitability
- Indicator plants
- Manure requirement
- Gravel content
- Gravel content

Water holding capacity, or water availability in general, is a crucial factor determining the productivity of a given soil. The availability of water depends not only on the amount and distribution of rainfall but also on the slope gradient, soil depth and structure, and SWC measures that help to retain surface runoff and improve infiltration. Most farmers classify soils in flat areas, on gentle slopes and with conservation structures as fertile. This is not surprising, as these soils benefit from deposition and accumulation of eroded material from upslope and are therefore deeper.

Soil depth is one of the important factors influencing water availability and likewise plays a crucial role in farmers' assessment of soil fertility. This is reflected in the local nomenclature: fertile soils are called *reguid hamed*, which literally means "thick soil," and poor, shallow soils are called *rekik*, meaning "thin".

Crop suitability: e.g. linseed and wheat are grown on less fertile soils because on fertile fields these crops grow too fast, which leads to low seed production and weak stems. Barley, maize and vegetables produce the best yields on fertile land.

Indicator plants: the presence or absence of certain plants such as *oxygonum atriplicifolium (chew mrakut)* and *xanthium spinosum (eshok mergem)* indicate the productivity of a soil. Both plants grow on fertile soils.

Manure requirement: less fertile soils require more frequent application and higher quantities of manure than fertile soils.

Gravel content: farmers attribute high importance to stones at the soil surface. On fields covered by stones, evaporation is reduced and moisture is better conserved than on fields without a stone cover.

Soil fertility classification

Farmers classify their land into three fertility classes: high, medium and low.

Local soil fertility classes

- *Rekik* (= shallow): low fertility
- *Maekelay*: moderate fertility
- *Reguid* (= deep): high fertility

For spatial distribution of soil fertility in the catchment see Map 7 on page 160.

Rekik hamed literally means shallow soil. The class of *rekik hamed* comprises soil of low fertility with a poor water retention capacity, occurring mainly in steep areas. When conserved, soil quality can differ between the lower part near the bund, where accumulation can lead to the development of a fertile soil, whereas the upper, poorer part is covered by a *rekik* or white soil.

Maekelay hamed is a soil of medium fertility with a moderate moisture storage capacity; occurs mainly on gentle slopes and in flat areas.

Reguid hamed literally means deep soil. This class describes fertile soils / land with a high water storage capacity. These soils occurs in flat to gently sloped areas; they often belong to the *duka* soil type (but: *duka* can also occur in sloping areas and with low to medium fertility!). ***Shiebet*** (= fertile land) is often used as a synonym.

Furthermore, east-facing land is said to be of lower quality because of the frequent easterly winds that tend to dry up the soil (especially in September/October).

Bodu is a term describing virgin soil or land that has not been cultivated for a long time. *Bodu* is considered to be the most fertile land (together with *duka*) because it is undisturbed. The structure of the topsoil is granular; farmers describe it as "match-head-sized pellets."

Before each periodical land redistribution, a committee of villagers classifies the entire village land into the three fertility categories mentioned above (fertile, moderately fertile and poor land). This classification forms the basis for an equal redistribution: each farmer will receive certain areas of fertile, moderately fertile, and poor land.

Farmers vary their seeding rate according to the soil fertility attributed to the field in question: they sow more seeds per area on productive (or fertile) land than on less fertile fields. This strategy helps to optimise production and the cost-value ratio, i.e. to minimise loss of invested inputs.

Farmers frequently reported that soil fertility in the study area is decreasing. They generally consider this process a big problem that occurs on almost all fields (see also “Shortage of manure and decreasing soil fertility,” page 33). Fertility management is thus a focal point of local soil and water conservation technologies; a wide range of traditional measures are intended to raise or maintain soil productivity (see “The importance of soil fertility management in local soil and water conservation,” page 104, and the information given in the fact sheets on SWC measures, pages 53 et sqq.).

Spatial variability and representativeness of local soil classifications

The heterogeneity of local soil knowledge poses an initial complication: even within a single village, similar soils may be referred to with different names (Tabor 1990; Schutjes and Van Driel 1994). This can be of considerable importance, since one of the main reasons for using a local classification is its capacity to facilitate communication between farmers, extension workers and researchers. If a local classification has a high spatial variability, it will not be able to change the fact that everyone speaks a different language. In such cases, it might be more useful to adopt a more general common classification capable of integrating aspects of the relevant local and scientific classifications. (Niemeijer 1995)

Generally the soil classifications and soil descriptions in the three village of the study area coincide to a high degree. Even though there are a few differences which are listed below: and variations from village to village in soil classification and soil description:

- Varying statements regarding the fertility status of red soil
- Variations / sub-types of white soil: *fahshaw* (greyish) or *hamukshtay* (ashy)
- *Tsetser*: defined partly as white quartz gravel, partly as small-sized gravel in general
- In Quandoba, farmers classified some soils as poor *duka*, while in *Afdeyu* farmers referred to the same type of soils as white soil
- While Afdeyu key informants classified shallow, stony hilltops as poor, Quandoba key informants partly rated them as moderately fertile; this might be due to the importance seen in the moisture-increasing effect attributed to stone covers

Using local approaches for a soil assessment implies that direct comparability of results is limited to an area with comparable (agro-) environmental conditions and crops, as well as a common language. Data accuracy is absolutely sufficient if the data is intended for further use in local (or regional) planning, monitoring and evaluation, participatory technology development, and other similar purposes. If intended for scientific use or for feeding a database with higher comparability requirements, results must first be transferred to a commonly known scientific classification system. In Eritrea, this is normally the FAO ISRIC / ISSS classification. The great advantage of using local classifications is the minimal effort required to collect data of high accuracy on the most important characteristics. Local farmers have good knowledge of the most critical factors of their soil system and its interactions with other natural or human-governed systems.

Scientific soil analysis and soil classification

For the present study, several soil pits where systematically tested and analysed by Eritrean soil scientists. The classification used was adapted from the FAO soil assessment system (FAO Soil Map of the World 1974 and Revised Legend 1988; the legend has been revised after 1988, but for better comparability with other studies cited in this document it was decided to follow the 1988 version). Results of the pit analysis were also used as a reference for numerous field samples. The location of the pits under analysis is based on the local classification and is statistically not representative. The number of pits to be analysed was determined in relation to the area covered by a certain (local) soil type. The selection of locations was discussed with local informants with the aim of achieving representative examples for the different soil types.

Physical soil properties

Soil texture and the related effects are by far the most important soil physical characteristics in local classifications. For scientific classifications, the texture class is also one of the major factors.

Table 23: *Results of physical soil analysis of the samples. Sample sites were selected according to the results of the local soil classification. Physical soil analyses were carried out by the NARI soil laboratory.*

Sample no.	Depth [cm]	Texture [%]				Stoniness	Slope gradient [%]	Local soil classification	Local fertility assessment
		Sand	Clay	Silt	Class				
AF-01	0-12	58.5	10.6	30.9	Sandy Loam	medium	13	*Duka*	medium
AF-01	12-40	53.6	11.5	34.9	Sandy Loam	medium	13	*Duka*	medium
AF-01	40-112	38.7	15.6	45.7	Loam	medium	13	*Duka*	medium
AF-04	0-40	37.0	26.1	36.9	Loam	high	n.a.	*Duka*	low
AF-04	40-75	24.9	13.8	61.3	Silt Loam	high	n.a.	*Duka*	low
AF-04	75-180	43.2	15.1	41.7	Loam	high	n.a.	*Duka*	low
AD-1	A.10	56.6	7.5	35.9	Sandy Loam	low	19	*Duka*	low
AD-2	A.35	34.4	13.3	52.3	Silt Loam	low	13	*Duka*	high
AD-3	A.35	59.0	12.1	28.9	Sandy Loam	low	16	*Duka*	high
AF-2	A.27	41.3	21.6	37.1	Loam	low		*Duka*	low
AF-4	A. 28	57.6	7.2	35.2	Sandy Loam	low	n.a.	*Duka*	medium
AF-5	27	51.5	9.3	39.2	Sandy Loam	low		*Duka*	medium
AF-13	A.26	57.7	9.6	32.7	Sandy Loam	low		*Duka*	medium
AF-02	0-20	26.1	24.1	49.8	Loam	low	21	Red soil	medium
AF-02	20-55	22.7	26.0	51.3	Silt Loam	low	21	Red soil	medium
AF-02	55-90	38.3	25.0	36.7	Loam	low	21	Red soil	medium
AF-3	A.18	57.2	14.5	28.3	Sandy Loam	medium		Red soil	low
AF-6	A.18	76.8	4.0	19.2	Loamy Sand	medium		Red soil	low
AF-7	A.21	46.0	15.2	38.8	Loam	low		Red soil	low
AF-9	A.13	32.8	23.3	43.9	Loam	low	34	Red soil	low
AF-12	A.32	32.9	28.2	38.9	Clay Loam	medium		Red soil	low
AF-03	0-20	35.4	12.6	52.0	Silt Loam	medium	26	White soil	low
AF-03	20-45	45.9	6.1	48.0	Sandy Loam	medium	26	White soil	low
AF-03	45-200	33.9	15.6	50.5	Silt Loam	medium	26	White soil	low
AF-1	A.10	49.2	7.3	43.5	Loam	medium		White soil	low
AF-8	A.22	49.2	10.3	40.5	Loam	medium		White soil	low
AF-10	A.13	48.8	13.8	37.4	Loam	low	10	White soil	low
AF-11	A.10	38.7	17.7	43.6	Loam	low	23	White soil	low
AF-14	A.25	56.2	8.5	35.3	Sandy Loam	low		White soil	low

n.a. = not analysed

Soil texture

The texture of the analysed soil samples cannot be differentiated in clusters of similar properties. As apparent in Figure 9, all results are fairly similar. Red soils are generally slightly richer in clay than the other soil types occurring in the area, which leads to the conclusion that the absence of clay is expressed in a paler colour. There is no link between clay content measured in the laboratory and soil fertility status as assessed together with the farmers; this most probably means that the exchange capacity of clays occurring in Afdeyu soils is rather low. Another possible explanation is that the local perception of soil fertility is not based on clay properties but on other factors, such as topography, total soil depth, land use and land management, and others.

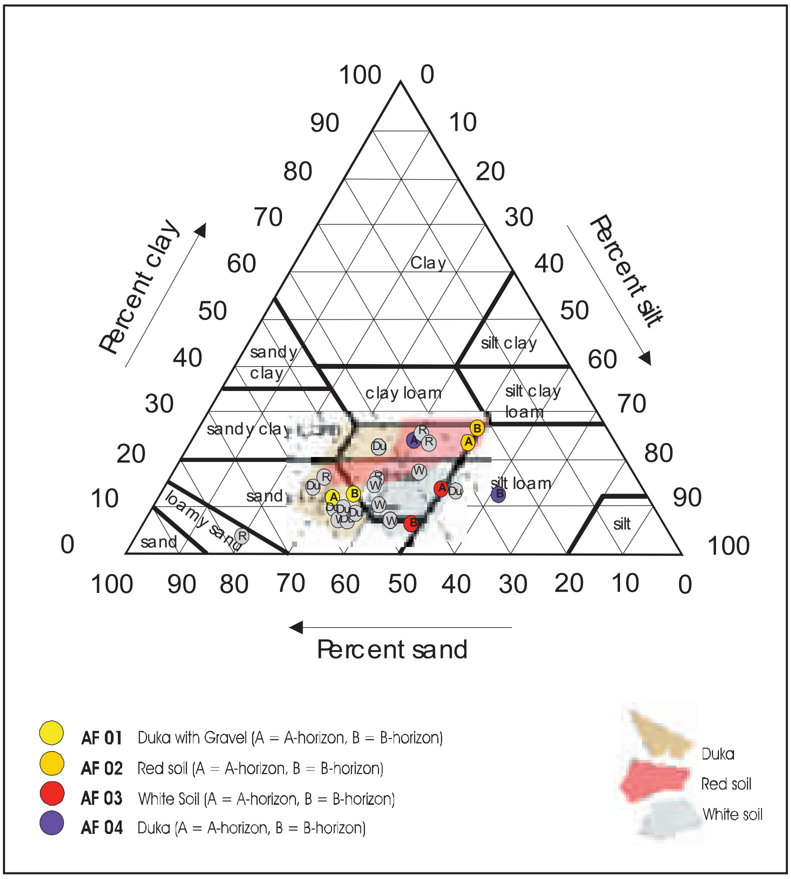


Figure 9: *Soil texture of the different soil types, based on the results in Table 23.*

Chemical soil properties

Analysis of the soil samples was carried out by the National Agricultural Research Institute of Eritrea (NARI) in Halhale. The focus of the analysis was on factors related to soil fertility and crop production. Table 24 below shows that the measured elements are available to plants only in small quantities. This fact is not surprising, given that many soils in the area have been cultivated for centuries and that pressure on the soil resources has led to an intensification of the land management system without sufficiently compensating the higher demand for soil nutrients by enhancing appropriate measures such as manuring, or application of chemical fertiliser. The poor soil properties are thus not the result of mismanagement or a lack of knowledge, but mainly of missing options (fertiliser not available or too expensive, no alternatives for generating off-farm income).

Table 24: Results of chemical soil analysis of the samples. Sample sites were selected according to the results of the local soil classification. Chemical soil analyses were carried out by the NARI soil laboratory. Topsoil samples (within the top 15 cm of the profile) are written in italics.

Sample no	**Depth** [cm]	**pH**	**Electric conductivity** [ms/cm]	**Organic matter** [%]	**P** [ppm]	**N** [%]	**Exchangeable cations** [Cmol/kg]				**CEC** [meq/100 g soil]	**Soil type**	**Soil fertility**
							Ca++	**Mg++**	**K+**	**Na+**			
AF-01	0–12	7.5	0.04	1.55	4.14	0.12	8	2	0.07	0.38	10.45	Duka	medium
AF-01	12–40	7.4	0.03	0.86	1.04	0.07	8	3	0.03	0.09	11.12	Duka	medium
AF-01	40–112	7.8	0.04	0.21	1.31	0.03	6	2	0.02	0.13	8.15	Duka	medium
AF-04	*0–40*	*7.1*	*0.02*	*1.78*	*1.14*	*0.1*	*11*	*3*	*0.06*	*0.11*	*14.17*	*Duka*	*low*
AF-04	40–75	7.3	0.02	0.24	0.27	0.03	5	2	0.02	0.09	7.11	Duka	low
AF-04	75–180	7.6	0.02	0.07	0.16	0.02	5	2	0.02	0.09	7.11	Duka	low
AD-1	*A.10*	*7.5*	*0.03*	*0.64*	*1.74*	*0.05*	*13*	*5*	*0.03*	*0.08*	*18.11*	*Duka*	*low*
AD-2	A.35	7.1	0.10	1.38	7.91	0.1	12	5	0.09	0.18	17.27	Duka	high
AD-3	A.35	8.0	0.17	3.43	48.28	0.17	15	6	0.76	0.35	22.11	Duka	high
AF-2	A.27	7.2	0.04	1.75	1.61	0.08	15	6	0.06	0.11	21.17	Duka	low
AF-4	A. 28	7.3	0.03	1.38	1.48	0.08	12	4	0.15	0.11	16.26	Duka	medium
AF-5	27	7.1	0.04	2.05	2.15	0.12	14	4	0.06	0.08	18.14	Duka	medium
AF-13	A.26	6.9	0.03	1.56	4.69	0.1	13	4	0.08	0.14	17.22	Duka	medium
AF-02	*0–20*	*7.1*	*0.02*	*0.48*	*7.79*	*0.05*	*7*	*3*	*0.03*	*0.15*	*10.18*	*Red soil*	*medium*
AF-02	20–55	7.1	0.02	0.45	0.54	0.05	8	2	0.02	0.08	10.10	Red soil	medium
AF-02	55–90	6.8	0.08	1.07	2.62	0.11	8	2	0.07	0.08	10.15	Red soil	medium
AF-3	A.18	6.9	0.13	2.69	1.48	0.16	12	4	0.10	0.18	16.28	Red soil	low
AF-6	A.18	7.3	0.05	2.96	2.55	0.15	11	3	0.10	0.12	14.22	Red soil	low
AF-7	A.21	7.3	0.06	1.09	4.83	0.07	10.5	3.5	0.11	0.13	14.24	Red soil	low
AF-9	*A.13*	*7.1*	*0.03*	*0.73*	*1.17*	*0.05*	*7*	*2*	*0.04*	*0.08*	*9.12*	*Red soil*	*low*
AF-12	A.32	7.0	0.10	1.97	12.77	0.11	12	4	0.14	0.19	16.33	Red soil	low
AF-03	*0–20*	*7.7*	*0.03*	*0.38*	*0.87*	*0.04*	*12*	*4*	*0.02*	*0.12*	*16.14*	*White soil*	*low*
AF-03	20–45	7.5	0.02	0.14	0.05	0.02	12	3	0.01	0.13	15.14	White soil	low
AF-03	45–200	7.7	0.02	0.14	0.22	0.02	11	3	0.02	0.15	14.17	White soil	low
AF-1	*A.10*	*7.6*	*0.03*	*0.95*	*0.54*	*0.05*	*10*	*3*	*0.05*	*0.08*	*13.13*	*White soil*	*low*
AF-8	A.22	7.0	0.07	1.39	1.69	0.07	9	2	0.05	0.14	11.19	White soil	low
AF-10	*A.13*	*7.0*	*0.03*	*0.78*	*7.95*	*0.06*	*6*	*2*	*0.14*	*0.08*	*8.22*	*White soil*	*low*
AF-11	*A.10*	*7.7*	*0.03*	*0.41*	*1.56*	*0.03*	*6*	*2*	*0.04*	*0.06*	*8.10*	*White soil*	*low*
AF-14	A.25	7.5	0.03	0.95	1.43	0.04	9	2	0.06	0.12	11.18	White soil	low

P=Phosphorus; N=Nitrogen; Ca=Calcium; Mg=Magnesium; K=Potassium; Na=Sodium; CEC=cation exchange capacity

pH (acidity)

As shown in figure 10, all measured pH are within the range of one pH unit and slightly alkaline. A soil pH within this range does not limit any functions for most cultivated plants, as long as the focus is rainfed agriculture. The pH values measured indicate possible problems only in relation with manganese (Mn): Mn deficiency symptoms can occur in some soils once the pH exceeds 6.5. However, a wide range of crops are sensitive to Mn deficiency. Mn exists in several oxidation states, the two most important being Mn^{2+}, associated with clay minerals and organic matter, and Mn^{4+}, present in insoluble oxides. Fertilising soils by applying additional Manganese is promising only if the soil pH, the organic matter content or the clay content are adapted and as long as no waterlogging occurs (waterlogging increases the redox potential, thereby negatively influencing Mn availability (Scheffer-Schachtschabel 1992; Lal, Rattan 2002).

It has been recommended that the pH of tropical soils be measured in a 0.01 M $CaCl_2$ suspension rather than an aquatic solution, because the latter method often leads to underestimation of pH values by 0.5 to 0.9 units (Landon 1991). Assuming on this basis that for some samples the “real” pH may be up to nearly one unit higher than measured, deficiency problems must be expected also for phosphorus, which is rendered unavailable to plants when the pH exceeds 8 (high pH values lead to fixation of P in the soil (Landon 1991).

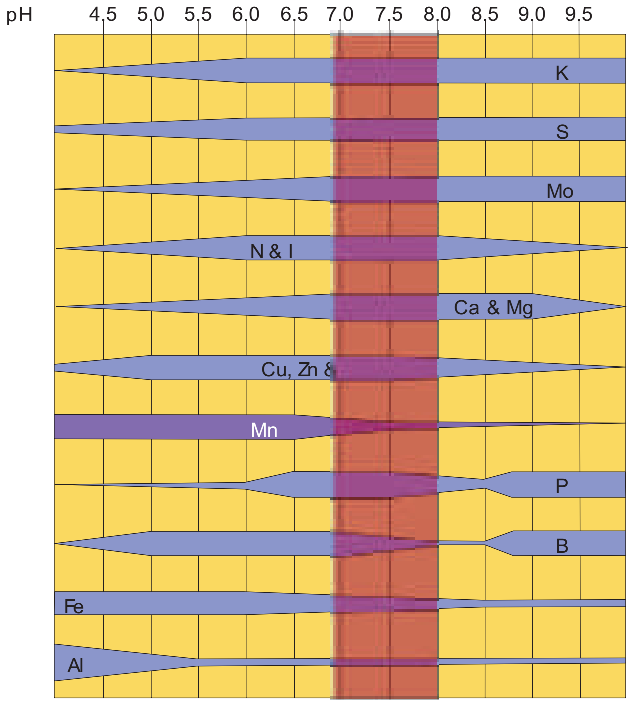


Figure 10: pH range of the analysed soil samples. Most samples were slightly alkaline, but within a range where the availability of essential nutrients (with the exception of manganese) to plants is not restricted. Soil pH was measured in a 1:5 soil / water solution.

K=Potassium
S=Sulfur
Mo=Molybdenum
N=Nitrogen
I=Iodine
Ca=Calcium
Mg=Magnesium
Cu=Copper
Zn=Zinc
Mn= Manganese
P=Phosphorus
Fe=Iron
Al=Aluminium

Organic matter

The organic matter content varies among the different samples from very poor to good (0.07-3.43%). Contents of less than 2% could be improved by means of adding manure, mulching, or adapted livestock management.

Plant Nutrients

All analysed macronutrients and the cation exchange capacity (**CEC**) are low in most samples. As mentioned above, the reasons for this are mainly the long history of cultivation and lacking restoration of soil macronutrients. Low yields in the study area are partially due to a lack of plant available macro- and micronutrients. A more extensive land use system or an adequately improved nutrient management system might help to improve soil conditions. An indicative minimum CEC-value in the top 30 cm of soil of 8-10 meq/100 g of soil (=Cmol/kg) is required for satisfactory plant growth, provided that other factors are favourable (FAO 1979).

Using the Olson analysis method a result of less than 5 ppm indicate a phosphorus deficiency in the soil as well as in the plants. The easily plant-available phosphorus in the soil is often bound to organic matter. It is thus not surprising that the soil with the highest organic matter content also shows the highest phosphorus content.

Nitrogen results (Kjeldahl method) are difficult to interpret because the soil samples were taken in spring, i.e. at the end of the dry season, when soil activity is still very low due to a lack of moisture. Nitrogen content is closely linked with soil biological activity and therefore varies considerably throughout the year. Values below 0.2% are classified as low, the only conclusion that can be drawn is that meaning at the time of analysis all soil samples were low in nitrogen.

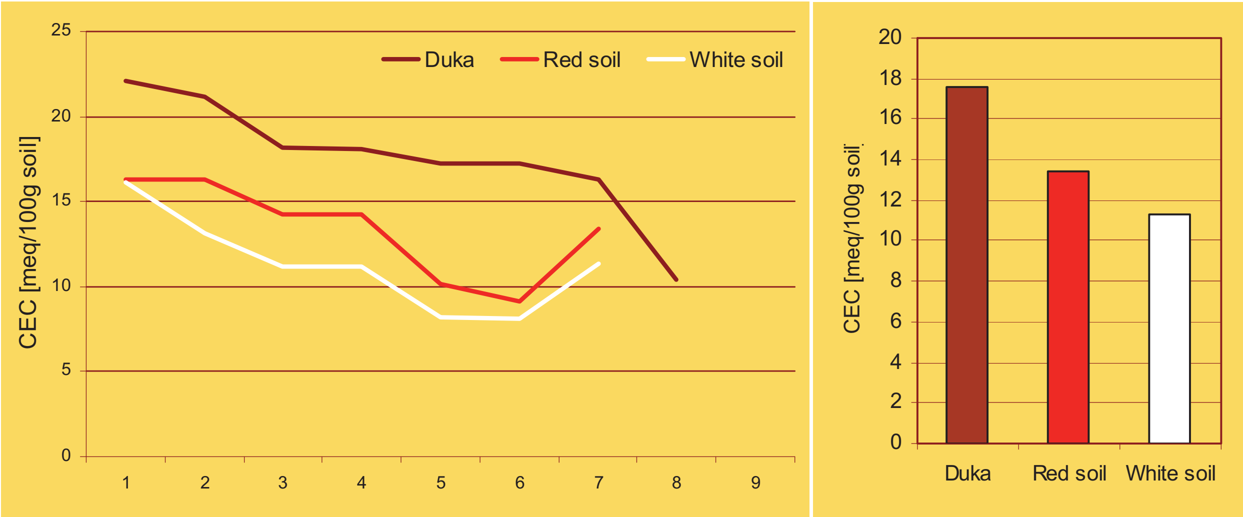


Figure 11: *Cation exchange capacity (CEC) as an indicator for soil fertility by soil type, as classified by local land users (left). The x-axis is numeric and indicates the number of samples. Mean CEC per soil type is shown on the right side. In local soil classification systems, soil fertility is one of the important differentiating characteristics. In contrast to scientific approaches, where soil fertility is explained through measured chemical parameters such as the CEC, local classification systems depend on tangible and visible values such as the annual yield and crop quality.*

Salinity

None of the soil samples are saline, since the results from the electrical conductivity tests show very low figures, i.e. less than 1dsm^{-1} (interpretation by NARI laboratory staff).

Summary of soil properties

Table 25 shows the summarized properties of the three major soil types according to the results of the laboratory analysis of soil samples and the classification of soil pits in the field.

Table 25: *Summarised results of scientific soil analysis*

Soil properties	*Duka*	Red soil	White soil
Soil texture	Sandy and silty loam	Mainly loam	Sandy loam and loam
pH	6.9 – 8	6.9 – 7.3	7.0 – 7.6
Organic matter	Low to medium	Low to medium	Very low to low
CEC	Mainly low, partly medium	Low	Very low to low
Soil fertility	Mainly medium, some high	Low	Very low to low

Classification of soil samples according to FAO

For this study only a few soil physical and chemical properties were analysed. A proper allocation of FAO soil types is therefore difficult. According to the data available, on the basis of physical and chemical characteristics exhibited according to ISRIC/ISSS/FAO (1998), all samples can be classified as cambisols in the FAO classification, some with luvic properties, but with a CEC of below 24 meq/100 g none of them can be classified as typical luvisols. Only the three profiles with a grey background in the column "sample no" in Table 26 below can properly be attributed to the FAO classification system, since this system often requires properties from more than one horizon for a correct allocation.

Table 26: *Results of the soil pit analysis, grouped according to the local soil classification. Attribution of the samples to the FAO classification is based on limited information and is therefore only indicative.*

Sample no	**Local soil type**	**FAO classification**	**Depth of A-horizon** (cm)	**Soil texture**	**CEC** (meq/g soil)	**Local fertility assessment**
AD-3	Duka		Ah.35	Sandy Loam	22.11	high
AF-2	Duka		Ah.27	Loam	21.17	low
AF-5	Duka		27	Sandy Loam	18.14	medium
AD-1	Duka		Ah.10	Sandy Loam	18.11	low
AD-2	Duka		Ah.35	Silt Loam	17.27	high
AF-13	Duka		Ah.26	Sandy Loam	17.22	medium
AF-4	Duka		A. 28	Sandy Loam	16.26	medium
SLM-AF-01	Duka	Cambisol	0-12	Sandy Loam	10.45	medium
AF-12	Red soil		Ah.32	Clay Loam	16.33	low
AF-3	Red soil		Ah.18	Sandy Loam	16.28	low
AF-7	Red soil		Ah.21	Loam	14.24	low
AF-6	Red soil		A.18	Loamy Sand	14.22	low
SLM-AF-02	Red soil	Cambic luvisol	0-20	Loam	10	medium
AF-9	Red soil		Ah.13	Loam	9.12	low
SLM-AF-03	White soil	Cambisol	0-20	Silt Loam	16.14	low
AF-1	White soil		Ah.10	Loam	13.13	low
AF-8	White soil		Ah.22	Loam	11.19	low
AF-14	White soil		Ah.25	Sandy Loam	11.18	low
AF-10	White soil		Ah.13	Loam	8.22	low
AF-11	White soil		Ah.10	Loam	8.1	low

Comparison of study results with secondary data from other surveys

Interestingly, the results of this study correlate rather well with other studies in the Eritrean highlands. Results can be compared, and even if details are locally specific there is a broad common understanding of soil types and their properties. A short comparison with similar studies is given in the section below.

Comparison of local soil classifications

Table 27 shows that the local soil types identified in the study area correspond to local typologies established in the highlands of Eritrea.

Table 27: Local classifications as used in other places:

		Afdeyu (this study)	Amadir[1]	Adi Behnuna[2]	Adi Asfeda[3]
		Central Highland Zone, 25 km northwest of Asmara	Central Highland Zone, 45 km southwest of Asmara	Central Highland Zone, 85 km southwest Asmara	Central Highland Zone, 13 km west of Asmara
Duka	Colour	brown	-		brownish
	Fertility	high	most fertile		fertile
	Water retention	high	good (deep soil)		
	Texture	fine			
	Other	highly variable gravel content, deep, good structure, hard when dry	few stones, main cropping area		
Keih hamed (red soil)	Colour	red			
	Fertility	moderate			
	Water retention	high			
	Texture	loamy			
	Other	variable depth, loose structure, plastic when wet, hardpans			
Tsa'eda hamed (white soil)	Colour	whitish, greyish			white
	Fertility	low			low
	Water retention	low			
	Texture	sandy			
	Other	well-drained, no cohesion, often shallow, no stone barrier at bottom of profile			
Walaka (black soil)	Colour	black		dark	
	Fertility	very fertile	good, limited to certain crops	high	
	Water retention	high	high	high	
	Texture	clay	clay	clay	
	Other	poor drainage, deep, free of stones, in plains only, cracking, hard to plough	hard to plough when dry, stones only on surface	flat areas, hard to plough when dry	
Hutsa	Colour				
	Fertility		low to moderate	low	
	Water retention		low to moderate	low	
	Texture			sandy	
	Other		developed along river bank	along river, degraded	
Ba'akel	Colour	light			
	Fertility	low	low		
	Water retention	low	low		
	Texture	sandy			
	Other	subsoil, hard			

This literature review is based on the following sources:
1) Amadir: Woldetensae Tewolde and Bissirat Dessalegn 2005
2) Adi Behnuna: Stillhardt and Frey 2001
3) Adi Asfeda: Personal communication from villagers 2004
Note: The results of the cited studies have been taken over without adaptation. The occurrence of phaeozems in Eritrea is controversial.

Hutsa is the only local soil type in the table above that was unknown to the farmers in the research area. This soil type is of alluvial origin and develops typically along sediment-rich rivers, which are non-existent in Afdeyu.

In Adi Behnuna farmers mention three additional soil types which were not identified in the study area:

Tsebaria: Occurs on volcanic parent material, generally sandy, on slopes. Classified as phaeozem according to the FAO classification. Since the tertiary volcanic activities did not reach the area of the central and northern Eritrean highlands, this soil type does most probably not occur in the area of Afdeyu.

Gelo: Soils of fair quality, with limited water storage capacity and generally high gravel and stone content. Development on the Precambrian basement.

Lesse: Accumulation of eroded soil material to the lee of a river, very fertile, good nutrient availability, optimal water conditions, but of very limited extent. This soil type was found along a perennial river; its development depends on the gradient of the riverbank and the frequent or permanent presence of river water. As such conditions are rare, this soil type is probably of minor importance compared to others.

Comparison of scientific surveys and assessments

Various soil surveys have been carried out in Eritrea (on the local and the national levels). The examples used here are not representative; rather, they were selected according to the criteria of known good quality and the availability of comparable data. The selection of studies presented and compared below thus reflects partner institutions and their networks rather than representing an objective national overview of soil surveys.

Dominant soil types in Eritrea

(Sources: RELMA 2002; complemented by FAO soil description in Thomas 1997 and FAO 1998)

Table 28 shows a selection of major soil types occurring in Eritrea according to the FAO classification, with their scientific designations and their equivalent names in the local language (Tigrinya). Note that the table lists the relevant soil types (those which have been mentioned by the farmers in the study area). According to this table, the soil types identified in the study area – red soil and *duka* – correspond to cambisols and luvisols. White soil – the third major type of the local classification – does not appear in this table. The stony lithosol does occur in the study area but was not recognised by the farmers as a soil type, as it is not arable and thus not relevant to them.

Table 28: *International and local soil nomenclature*

FAO nomenclature	Tigrinya translation
Cambisols	*Keih hamed* (red soil)
Lithosols (leptosols)	*Kontera / Meraguzo*
Fluvisols	*Tswar hamed / Ekub hamed*
Luvisols	*Dukua / Ba'ekel*
Vertisols	*Walaka*

Cambisols: Brown or red soils, well-developed, but relatively little weathered; B-horizon with cambic properties, CEC (Cation Exchange Capacity) > 16meq/100 g clay; not showing clay (or any other) accumulation. Occurring often on sloping or undulating land. The texture of the subsurface horizons must be sandy loam or finer, with at least 8 percent clay by mass and a thickness of minimum 15 cm. These soils naturally form on medium- to fine-textured parent materials under any climatic, topographic, and vegetative-cover conditions. They differ from Leptosols and Regosols by their greater depth and finer texture and are often found in conjunction with Luvisols.

Lithosols (FAO 1974) / **leptosols** (FAO 1988): Lithosols were classified as 'shallow soils, less than 10 cm deep, developed over hard rock (mineral soils), mostly located on steep, erosion-prone slopes' in the

1974 FAO classification system, which was revised in 1988. They are now grouped under **leptosols**: less than 50 cm soil depth or very stony and unconsolidated material (< 15% fine earth above 125 cm).

Fluvisols: Young recently deposited soils, developed on alluvial deposits of river plains, deltas, former lakes, and coastal areas. Sediments consist of eroded material from uplands and mountains, often stratified with bands of coarse and fine materials. Depositional rather than pedogenetic profiles. Good fertility, if deep, good for agricultural use.

Luvisols: Red, brown or yellowish illuvial soils with high base saturation in the B-horizon. Accumulation of clay minerals and/or iron in B-horizon (or even formation of hardpans). CEC in the B horizon > 24 meq/100g clay and BSP (Base Saturation in Percent) > 50 throughout the whole soil profile; surface sealing can occur, leading to low permeability and hampering root distribution. Content of plant available phosphorus is low to moderate. Generally good for agricultural use.

Vertisols: Dark, montmorillonite-rich and frequently deep soils containing very heavy clay, occur only in flat areas with pronounced dry seasons. Develop large deep cracks (polygonal pattern) when dried out. During the wet season the clay swells and causes pressure in the subsoil. Agricultural use is limited due to difficult land preparation. Poor drainage and frequent waterlogging. Even if organic matter content is often less than 3%, these soils are of high fertility and, if properly managed, of high agricultural value.

General soil map of Eritrea

According to the General soil map of Eritrea (FAO 1994) the following three soil types are predominant in Afdeyu:

- stony cambisols (dominant)
- on ridges: associated with lithosols (new classification: leptosols)
- on valley floors: associated with fluvisols

The dominant soil type recognised in the Afdeyu correlates well with the dominant soil type as indicated in the General Soil Map of Eritrea. The scale of the general soil map does not allow more detailed comparisons.

Soil survey in Adi Behnuna

A livelihood assessment was carried out in Adi Behnuna (south of Areza, 85 km southwest of Asmara) and surrounding villages in 1999. The focus was not on soil science, but a soil survey in Adi Behnuna resulted in the definition of soil types by local stakeholders.

Adi Behnuna is situated in the southern Part of Eritrea, near the River Oubel. Genetically the area is influenced by tertiary volcanic activities. Consequently, soil genesis is different from that in the study area and different soil types can be found. The Adi Behnuna study is the only one among those mentioned here that describes a phaeozem, locally called *gelo*, therefore it is impossible to draw conclusions about the representativeness of its description. In addition, this survey provides the only analysis of a *walaka* (= vertisol according to FAO classification), a dark clay soil with very typical properties such as swelling and shrinking in relation to water content. This soil type is known by most highland farmers, which means that they always mention it, even if it does not occur in their area. In general, the soils in Adi Behnuna contain more sand than those analysed in the central highlands. They are therefore more severely affected by drought (faster percolation, lower water storage capacity, soils dry out more rapidly). Chemical analysis revealed the same problems as in other places. Intensive use leaches out the soils and leads to low plant available nutrient contents.

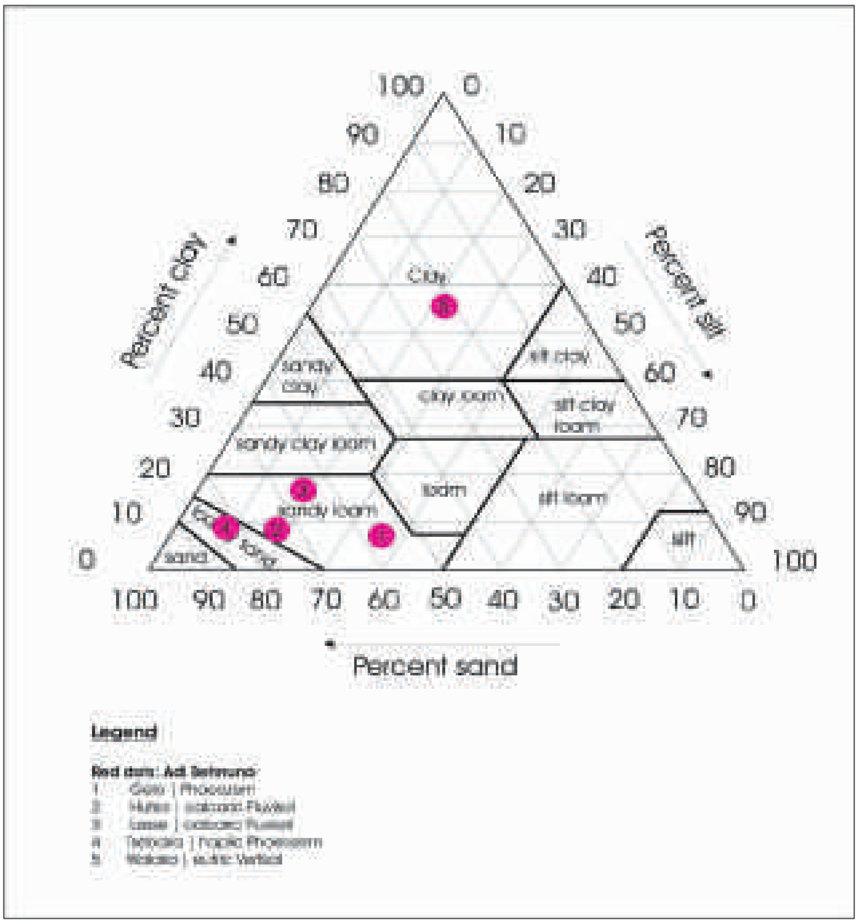


Figure 12: Results of soil survey carried out in Adi Behnuna in 1999.

Afdeyu soil surveys (2000 and 2004)

As described in the legend of Figure 12, the results indicated by the squares 'A' and 'B' are from soil samples taken in Afdeyu and analysed by Virginia Dawod in 2004. The diagram clearly shows that both of these samples had a higher clay content than was measured in most of the samples analysed by the study team of the report in hand, as well as in the samples collected by Virginia Dawod in 2000. The exact location of the analysed pits is not known to the authors of the study in hand, therefore it is impossible to determine whether this difference is due to diverging sample locations or whether it has other reasons. However, when comparing the results, it is obvious that all major divergences are caused by the difference in clay content. All other differences are minor, and it is possible to conclude that the dominant soil texture in Afdeyu is loamy.

Concerning soil chemistry, the conclusions drawn by Virginia Dawod in 2000 and 2004 are similar to those put forward in the present study. The pH values of most samples were found to be within an optimal range, excluding negative effects on plant growth. Organic matter content was generally found to be rather low (which is not surprising in a semi-arid environment), and the level of plant available (macro-) nutrients was low to medium.

Table 29: Results of analysis of soil samples from two pits in Afdeyu studied by Virginia Dawod in 2004. Direct comparison is difficult because the depth of the samples was different and sample sites are not specified. However, it can be said that Profile 3 is richer in clay, lower in pH and Ca, and higher in CEC. BS = Base saturation in % of the total CEC; pH: soil/water (1:2)

Horizon	Profile Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	pH	Org. C (%)	Total N (%)	C/N	CEC	Exchangeable cations				BS
											Ca	Mg	K	Na	%
										cmol kg^{-1}					
Profile 3															
3A	0–20	22.8	34.1	42.3	Clay	6.5	1.85	0.13	14.2	28.1	20.6	1.8	1.5	1.4	90.0
3B	20–82	15.1	37.5	46.8	Clay	6.2	0.43	0.05	8.6	30.3	21.5	1.7	1.5	1.5	86.5
3C	82–109	14.2	35.8	49.5	Clay	6.2	---	---	---	31.5	22.3	1.7	1.3	1.5	85.1
Profile 4															
4A	0–5	35.6	30.1	33.8	Clayey loam	7.5	1.95	0.13	15.0	27.2	23.4	1.6	0.8	2.2	100
4B	5–52	24.4	38.7	36.5	Clayey loam	7.5	1.87	0.13	14.4	28.5	24.8	1.6	0.8	2.2	100
4C	52–92	33.5	45.2	20.9	Silty loam	7.9	---	---	---	22.6	18.8	1.5	0.4	2.8	100

Table 30: Soil sample analysis, Afdeyu 2000. (Source: Virginia Dawod et al 2000). EC = electrical conductivity; OM = organic matter. It is noticeable that the clay content in all these samples is much lower than in the 2004 samples. Since no information is available on sample sites and sample depth it is not possible to make further conclusions on the results of the analysis.

Sample No	**Particle size**			**Texture**	**Soil depth** [cm]	**pH**	**EC** [dS/m]	**P** [ppm]	**Ca + Mg** [cmol/kg]	**K** [cmol/kg]	**Na** [cmol/kg]	**OM** [%]
	Sand	Silt	Clay									
AGH 1	41.9	48.7	9.4	Loam	33	6.8	0.05	6.5	8	0.03	0.19	1.0
AGH 2	48.8	41.3	9.9	Loam	68	7.0	0.08	6.6	8	0.31	0.12	1.1
AGH 3	51.3	40.4	8.3	Loam	>100	7.3	0.05	5.6	12	0.2	0.09	N
AGP 1	43.2	45.0	11.8	Loam	82	6.9	0.05	9.1	22	0.29	0.10	1.0
AGP 2	43.9	44.6	11.5	Loam	81	7.0	0.04	6.9	14	0.21	0.08	0.7
AGP 3	42.5	45.7	11.8	Loam	81	6.8	0.05	9.0	16	0.38	0.16	1.0
GH 1	45.8	44.3	9.9	Loam	30	6.7	0.07	9.7	8	0.28	0.09	0.9
GH 2	44.1	44.5	11.4	Loam	45	6.7	0.06	14.3	21	0.34	0.11	1.5
GH 3	40.7	47.4	11.9	Loam	72	6.4	0.08	6.4	13	0.25	0.07	1.1
GH 4	37.1	49.3	13.6	Loam	78	6.4	0.08	9.6	9	0.31	0.10	1.2
GH 5	37.1	47.6	15.3	Loam	70	6.7	0.06	9.5	18	0.28	0.11	1.0
GH 6	38.9	46.6	14.5	Loam	54	7.4	0.18	9.7	26	0.26	1.26	0.9
GH 7	33.7	53.6	12.7	Silty Loam	82	8.2	0.28	9.7	16	0.34	1.72	0.8
GH 8	51.3	39.0	9.7	Loam	86	6.7	0.07	9.3	8	0.24	0.07	0.6
GHU 1	52.4	39.5	8.1	Sandy Loam	79	7.1	0.04	7.2	8	0.20	0.07	0.8
GHU 2	35.5	44.0	20.5	Loam	19	6.7	0.06	6.7	14	0.56	0.12	2.6
GHU 3	43.2	46.2	10.6	Loam	>100	6.6	0.16	5.5	13	0.20	0.22	1.0
IRU 1	34.5	55.0	10.5	Silty Loam	70	7.1	0.06	6.7	9	0.21	0.09	N
IRU 2	43.0	49.6	7.4	Loam	77	7.1	0.05	5.9	16	0.21	0.12	0.7
IRU 3	49.8	44.4	5.8	Sandy Loam	>100	7.0	0.06	6.7	16	0.27	0.17	N
IRP 1	42.7	50.0	7.3	Silty Loam	>100	6.6	0.06	14.7	9	0.50	0.11	0.1
IRP 2	46.4	47.9	5.7	Sandy Loam	>100	6.6	0.05	10.4	11	0.48	0.20	1.0
IRP 3	21.5	70.0	8.5	Silty Loam	>100	6.4	0.06	12.0	16	0.55	0.31	1.8
IRP 4	29.7	62.7	7.6	Silty Loam	>100	6.5	0.31	15.7	12	0.56	0.49	1.8
IRP 5	34.5	59.3	6.2	Silty Loam	>100	6.2	0.15	10.6	17	0.56	0.34	1.6

Comparison of local knowledge with a scientific approach

Most soil types found in the study area are rather similar, differing mainly in soil depth, soil colour, and water retention capacity. The local classification identifies three main soil types that can be attributed to cambisols and cambic luvisols in the scientific FAO soil classification. These two FAO soil types differ mainly in clay content and, in relation to this, in their cation exchange capacity. Based on the soil sample analysis carried out in the present study, it is not possible to differentiate in the FAO classification between soils locally classified as *duka* and soils locally classified as white soils. This is rather interesting, since farmers described the soil structure, colour, and soil fertility of the two soil types to be fairly different from each other.

Comparison of the study results with other soil surveys has revealed that local terms for the different soil types as used in Afdeyu are common throughout the central highlands of Eritrea. This gives the results of all studies a certain importance, since the terms used for the local classifications are similar over a large area.

Table 31: Comparison of local and scientific soil nomenclatures as mentioned in several available soil studies from the Tigrinya-speaking regions of Eritrea.

FAO[1]	RELMA[2]	Adi Behnuna[3]	Gurtner et al.[4]	Corbeels et al.	S. Zaid[6]
Cambisol	*Keih hamed**		*Duka* *Tsa'eda hamed*	*Bahakel*	*Ba'akel, Shiebet*
Luvisol	*Duka, Ba'akel*		*Keih hamed*	*Keih meriet**	
Vertisol	*Waleka*	*Waleka*	*Walaka* *Tselim hamed*	*Walaka* *Tselim meriet**	
Phaeozem		*Tsebaria, Gelo*			
Leptosol**	*Kontera* *Meraguzo*		*Rocky soils****	*Chincha* *Hutsa*	
Fluvisol	*Ekub hamed* *Tswar hamed*	*Hutsa, Lesse*	*Tswar hamed*		

* *meriet* = earth, land; *hamed* = soil; both words are used and are synonymous with regard to the local soil assessment.
** formerly classified as Lithosol
***occurring in the study area (and recognised by locals), but not relevant for agriculture and thus not classified as local soil type
Sources:
[1] FAO soils map of the world 1984
[2] Amanuel Negassi et al (RELMA) 2002
[3] Adi Behnuna: Stillhardt and Frey 2001
[4] Amadir: Woldetensae Tewolde and Bissirat Dessalegn 2005
[5] Mark Corbeels et al, 2001
[6] Semere Zaid, 2002

Vertisols are easy to be identified / determined in the field, and their characteristics are well-known: dark, rich in clay, with shrinking and swelling properties. It is therefore not surprising that the allocation of vertisols is very consistent.

Luvisols and **cambisols** are diagnostically close to each other, the main difference is the occurrence of an illuvial B-horizon in luvisols. Luvisols can develop from cambisols when the pH is not too low and clays are dissolved and moved downwards in the soil profile. This transformation process is continuous, thus even for experts it is not always easy to decide without laboratory analysis on whether a soil is still a cambisol or whether it has already fully developed into a luvisol (increase of clay content in the B-horizon, higher CEC in the B-horizon). Often cambisols are slightly more fertile than luvisols, but both are favourable to good agricultural soils. When looking at farmers' diagnostic characteristics – soil colour, plant availability of water, amount and quality of yield (soil fertility) – it becomes obvious that they cannot differentiate these two soil types. Consequently, *ba'akel*, *duka* and *keih hamed* (or *meriet*) all refer both to cambisols and luvisols. For a rapid assessment of soil types, the local classification is generally accurate enough; for scientific purposes, an additional analysis of whether there is an illuvial B-horizon is sufficient to attribute a given soil unambiguously to one of the FAO soil types.

Fluvisols are called *tswar hamed* in two of three studies. Although all available information is consistent, the total sample is too small to draw any conclusions.

Leptosols and **fluvisols** are both rather poorly developed soils with no distinct B-horizon. The word *hutsa* might refer to poorly-developed soils, but again, the two examples in Table 31 are no sufficient basis for drawing reliable conclusions or estimating the fertility status of these soil types.

The participants of the final stakeholder workshop: Farmers and representatives of various institutions dealing with extension and research in the context of agriculture and sustainable land management. Part 4 presents the main findings and lessons learnt based on the outcome of the study and the final workshop (Photo 35).

Synthesis

Maps

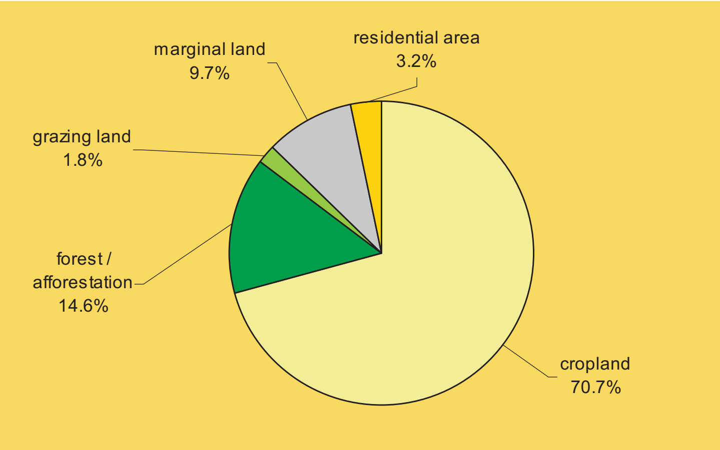
Conclusions and recommendations

Summary of final stakeholder workshop and outlook

Maps

Land use

The study area can be divided into 5 major types of land use: cropland, grazing land, woodland, marginal land (no specific use) and residential area. The distribution is as follows:



Land use type	Area (ha)
Cropland	419.06
Woodland (includes afforestation)	86.14
Grazing land	10.85
Marginal land	57.47
Residential area (village)	19.15

***Table 32** (above): Area coverage of different land use types (in hectares)*

***Figure 13** (left): Land use types (in percentage)*

Cropland covers the vastest part of the study area, extending from the fertile plains and valley bottoms to the steep slopes located around the settlements and to the west of the study area. These have been converted to cropland through terracing. However, the first impression may be misleading: access to cropland is extremely low at 0.86 ha per capita. A closer look at the crops shows that most of the cultivated land is sown with wheat (44%) and barley (28%).

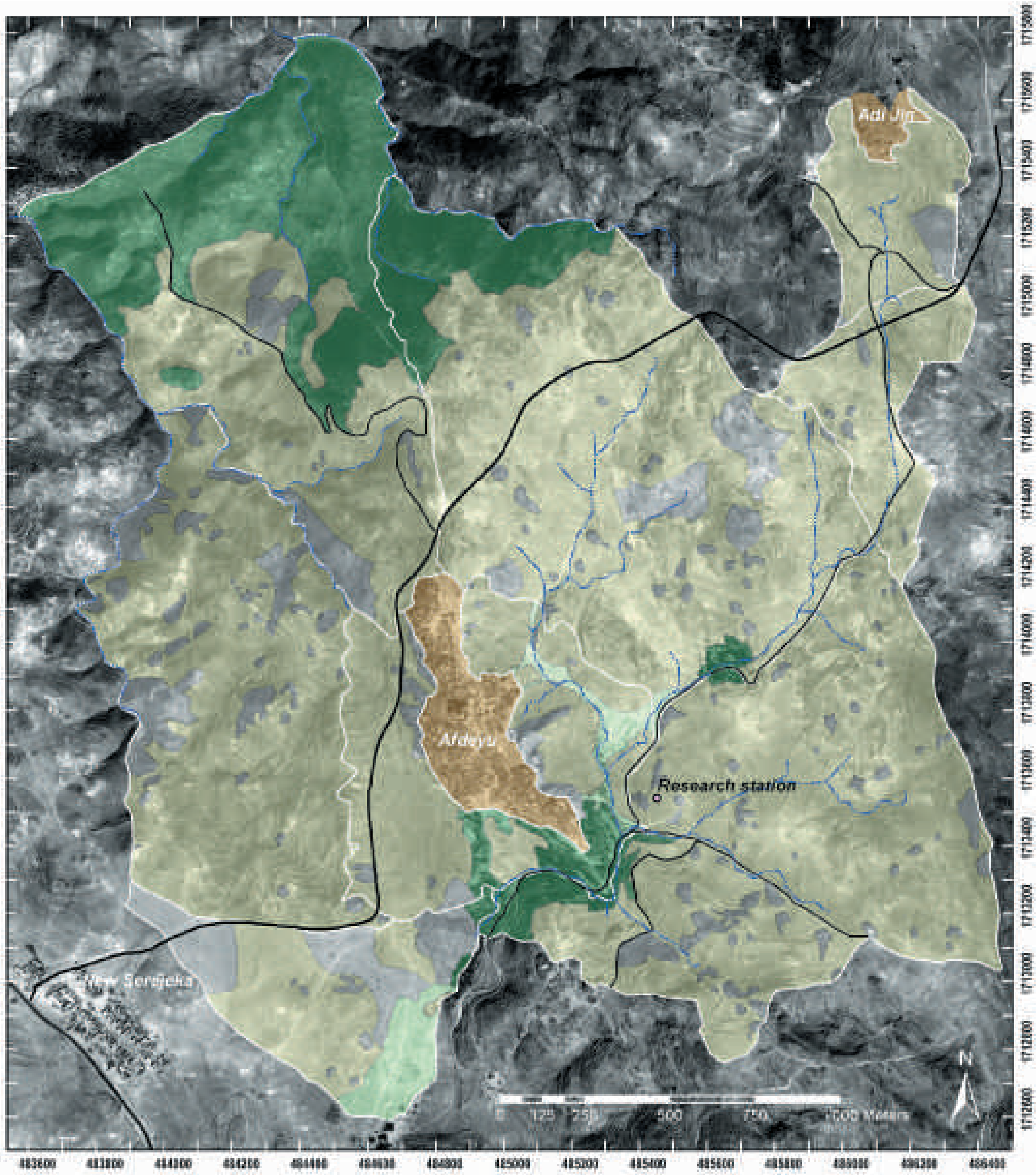
There is an extreme shortage of grazing areas, which covers less than 2% of the study area. Designated grazing land is limited to the plains northeast of Afdeyu (valley bottom) and south of Afdeyu (towards Serejeka).

Forests and woodlands, mostly covering steep slopes, include: 1) a large communal afforestation area on the western slopes of the study area, which is, to a limited degree, used for grazing; 2) an afforestation area in the valley bottom near Afdeyu village with trees planted and owned individually; 3) a small locally enclosed area where natural regeneration has taken place in combination with some planted species (sacred area in Grat Hamushte, Afdeyu); other local enclosures (e.g. in Adi Jin and Quandoba) are located outside the study area. For further information on forest / woodland see "Vegetative measures", page 152.

Marginal land includes 1) rocky outcrops; 2) areas with very shallow, stony and unproductive soils, or 3) other uncultivated land without any specific use. Processes of degradation will lead to an increase in this category unless appropriate interventions take place.

The residential areas of the two villages located within the study area (Afdeyu and Adi Jin) cover almost 20% of the area. Situated on hilltops, they are surrounded by relatively steep terraced slopes. The area occupied by roads is not included in this category.

***Map 2** (opposite page): Land use types →*



Land use types

- Cropland
- Forest/afforestation
- Grazing land
- Marginal land
- Residential area

Other features

- Streams
- Roads
- Village zone boundaries

Map information

Scale:	1:16,000
Raster resolution:	1 m
Grid interval (UTM):	100 m
Projection:	Universal Transverse Mercator (UTM)
UTM Zone:	UTMZ 37
Datum:	WGS-84

Data sources

Satellite image:	GEOEYE 2000 (IKONOS II)
Land use types:	CDE/NARI Field survey 2004
Other feature data:	SLM Database 2004

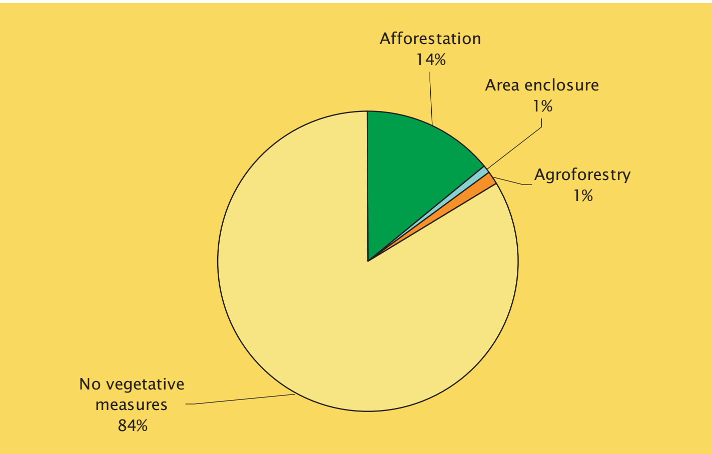
SWC measures

Agronomic measures such as crop rotation, fallowing, contour ploughing, mixed cropping, and compost application are repeated annually. Their appearance depends on seasonal changes. Many agronomic measures are not visible during large parts of the year, which makes comprehensive mapping impossible. However, some statements can be made on the spatial distribution of agronomic measures. Many of them are an integrated part of farming activities and are applied on most cultivated plots (crop rotation, fallowing, local ploughing system). Of all agronomic measures, the use of compost / manure and fertiliser seems to have the smallest area coverage. Due to its limited availability it is primarily applied in Gedena to replenish soil nutrients on the intensively used area around the settlements which is never fallowed, and where crops with higher fertility requirements (such as maize and potatoes) are grown. Moreover, when available, manure and chemical fertilisers are used to improve soil fertility on plots outside Gedena after three consecutive cropping periods. Mixed cropping (barley and wheat) is again generally practised, especially in the third year of the crop cycle as yields tend to decrease. Intercropping is applied particularly in the intensively used Gedena area. Stone mulching, being a natural condition, depends largely on land users' preferences. The stone cover is removed in places where it impairs the growing process of certain crops, such as onions and potatoes (in Gedena).

Vegetative measures can be divided into two classes:

1) Linear measures: grass strips, live fences, trees planted along bunds. Note that the map gives a wrong visual impression regarding linear measures, since these actually do not cover the whole units, but only one (or several) lines within the respective polygon.
2) Measures that extend evenly over a certain area: afforestation and natural regeneration of vegetation.

Grass strips are planted on contour bunds (with an earth component) and on terrace risers. Their potential applicability thus stretches out over approx. 90% of the cultivated land. In reality they were implemented only on a very small area on a fertile plain in Grat Hamushte, and have nearly disappeared since: the open grazing system and droughts make their proper establishment very difficult. Live fencing was used mainly in Gedena to protect fields and settlements against animals, as well as along roadsides. Only very few fences have remained in good shape, basically around the residential area of Adi Jin. Naturally growing grass strips on bunds have not been mapped; they occur on most permanent earth bunds / stone and earth bunds. Trees on bunds (as the most common type of agroforestry in the area) are not at all accepted by local land users. They were found only within one single polygon: in midst of the afforestation area in Kelkel.



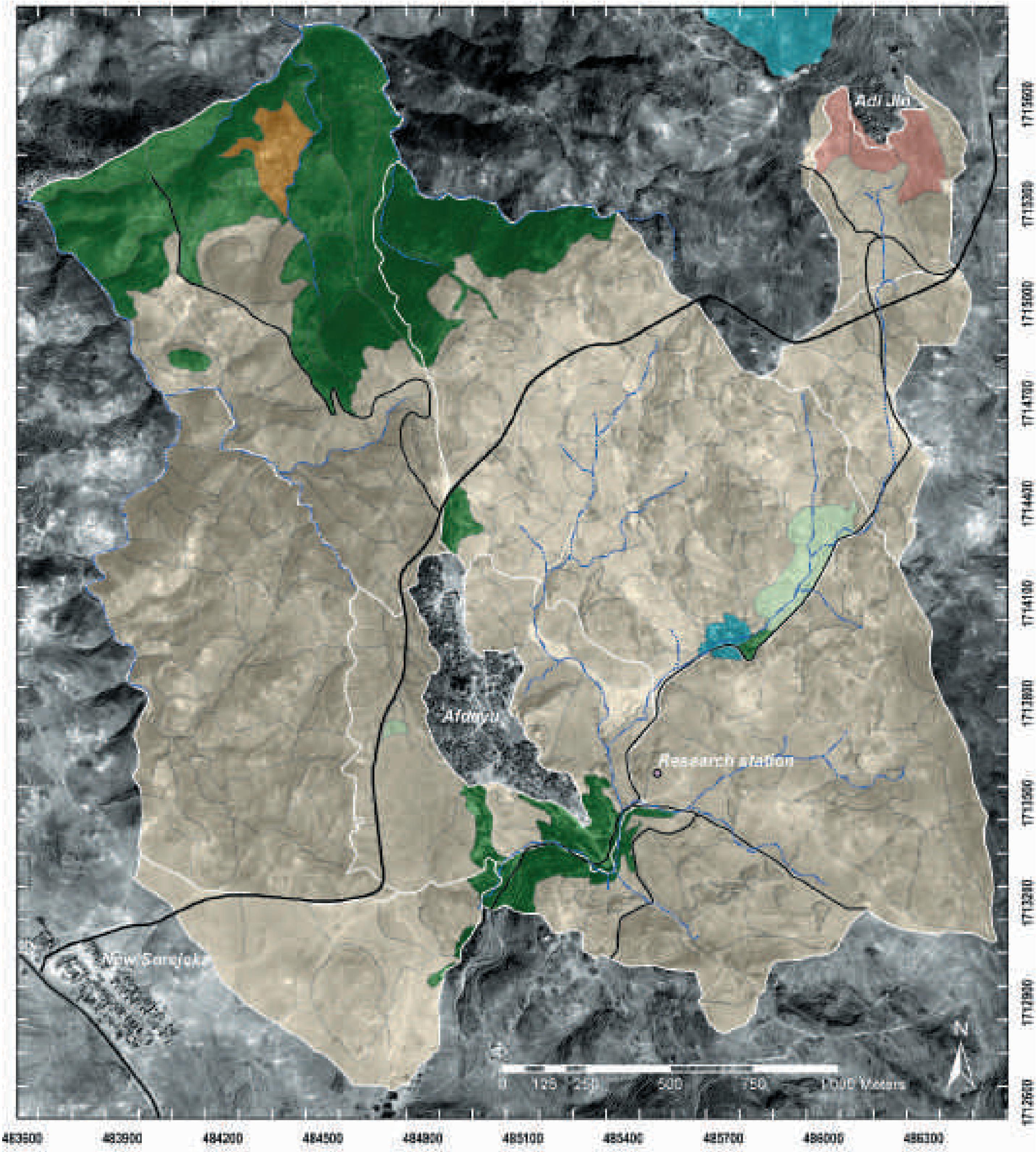
Vegetative measures	Area (ha)
Afforestation	81.63
Natural regeneration	4.55
Agroforestry	7.56
No vegetative measures	481.22
Total	574.96

Table 33 (above): Area coverage of vegetative measures (in hectares)

Figure 14 (left): Area coverage of vegetative measures (in percentage)

Woodlands are concentrated on the steep marginal slopes that are not suitable for crop production and mostly situated far from the settlements. The most prominent example in the study area is the upper Hayelo catchment (to the west, in Kelkel and Grat Hamushte), where an intensive afforestation programme has been implemented, including establishment of hillside terraces / stone bunds, micro basins and check dams to control erosion and protect the dam further downstream from siltation. The trees near the village of Afdeyu are privately owned. They are also planted on steep marginal sloping land (around the old collapsed dam).

Map 3 (opposite page): Vegetative measures →



Vegetative measures

- No vegetative measures
- Grass strips
- Live fences
- Afforestation
- Enclosure
- Agroforestry

Other features

- Streams
- Roads
- Village zone boundaries

Map information

Scale:	1:16,000
Raster resolution:	1 m
Grid interval (UTM):	100 m
Projection:	Universal Transverse Mercator (UTM)
UTM Zone:	UTMZ 37
Datum:	WGS-84

Data sources

Satellite image:	GEOEYE 2000 (IKONOS II)
Land use types:	CDE/NARI Field survey 2004
Other feature data:	SLM Database 2004

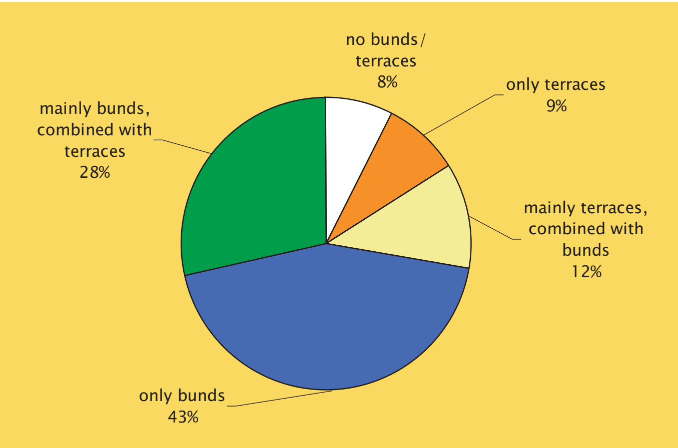
Nonetheless, afforested areas, consisting mainly of eucalyptus and acacia species, cover 14% of the study area. Most villages have traditionally maintained local enclosures for many generations, where natural regeneration of the vegetation cover is combined with introduced (planted) species. These areas ensure access to fuelwood and timber, which is extremely scarce in the area. There is only one small enclosed area of religious importance inside the study area; larger enclosures are situated just outside the study area.

Structural measures can be divided into 3 major groups:

1) Level bunds / terraces: traditional stone terraces, stone and earth bunds, hillside terraces.
2) Water harvesting / diversion : diversion bunds, micro-basins, tied ridges, small dams, irrigation.
3) Gully control: check dams, reclamation of pipe erosion

Level bunds / terraces: Government campaigns covered almost the whole area with stone and earth bunds for catchment protection: only 7.5% of the study area feature neither terraces nor bunds. A large part of 43.6% is protected by bunds alone. The bunds can be subdivided into stone bunds, earth bunds, and stone and earth bunds. On the map, they are included in one single class, level bunds, for the sake of a readable visualisation. The combined (stone and earth) bund is the most common form. Earth bunds are established where the availability of stones (for stabilisation) is limited or where they develop from traditional field boundaries (often in flat areas), whereas stone bunds occur on steep slopes with stony, shallow soils or in places where farmers intentionally want the bunds to be water permeable (e.g. in plains and on gentle slopes with a risk of waterlogging). The introduced bunds extend into marginal (less productive) areas, also covering vast parts of the steep and intersected area outside the Mayketin catchment to the west of the new road, as well as to the east of the old road (Aguari'e zone, Afdeyu). Remarkably these areas are also less accessible (distance to village). Note that hillside terraces have been mapped as stone (and earth) bunds, as their appearance is basically identical in the study area. While stone and earth bunds are applied on cropland, hillside terraces dominate on the steep slopes of afforestation areas.

The traditional high stone terraces prevail in the Gedena zone around the villages where steep slopes were levelled and converted to high-potential cropland. The terraces efficiently conserve water, soil and applied manure on these intensively used slopes, thus optimising conditions for cash crops. Outside Gedena, they were established in valley bottoms to extend arable land into marginal areas.



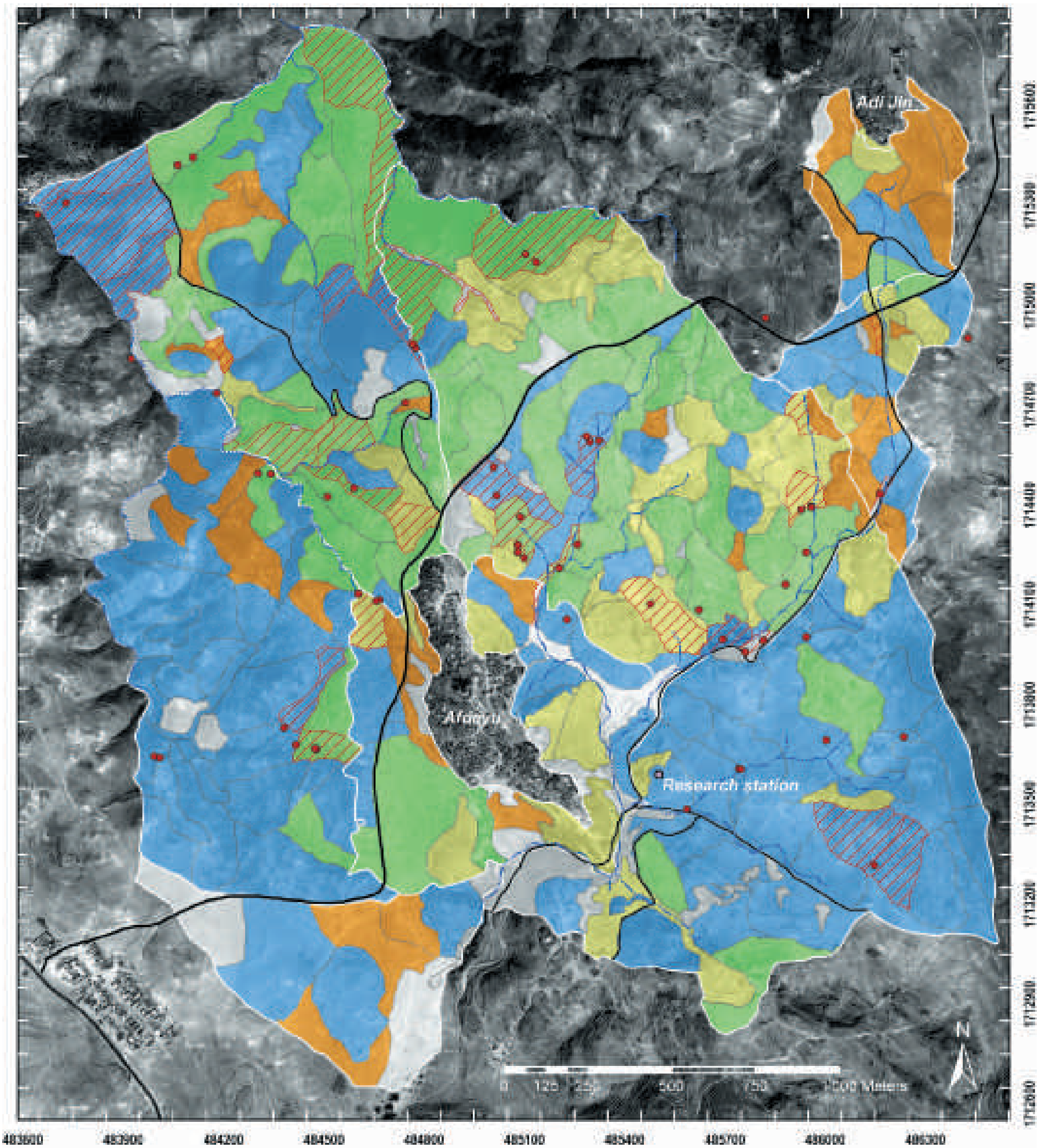
Structures	Area (ha)
Without bunds / terraces	42.94
Terraces only	49.27
Mainly terraces, combined with bunds	67.41
Bunds only	250.78
Mainly bunds, combined with terraces	164.56
Total	574.96

Table 34 *(above): Area coverage of bunds and terraces (in hectares)*

Figure 15 *(left): Area coverage of bunds and terraces (in percentage)*

Usually bunds and terraces occur in combination. Introduced bunds complement existing old terraces in various ways: 1) bunds on top of existing terraces help counter siltation / increase the terrace risers; 2) bunds between existing terraces support SWC where spacing is wide and the terrace bed is not level; 3) bunds below the risers of existing terraces replace the latter, following the contour line; 4) bunds link individually applied terraces to close the gaps and establish a continuous barrier. Combinations of introduced bunds and local terraces occur in 40.3% of the study area.

Map 4 *(opposite page): Structural measures: bunds and terraces; checkdams →*



Structural measures (I)

- No bunds / terraces
- Only terraces
- Mainly terraces, comb. with bunds
- Only bunds
- Mainly bunds, comb. with terraces
- Checkdams
- Checkdams (geo-referenced)

Other features

- Streams
- Roads
- Village zone boundaries

Map information

Scale:	1:16,000
Raster resolution:	1 m
Grid interval (UTM):	100 m
Projection:	Universal Transverse Mercator (UTM)
UTM Zone:	UTMZ 37
Datum:	WGS-84

Data sources

Satellite image:	GEOEYE 2000 (IKONOS II)
Land use types:	CDE/NARI Field survey 2004
Other feature data:	SLM Database 2004

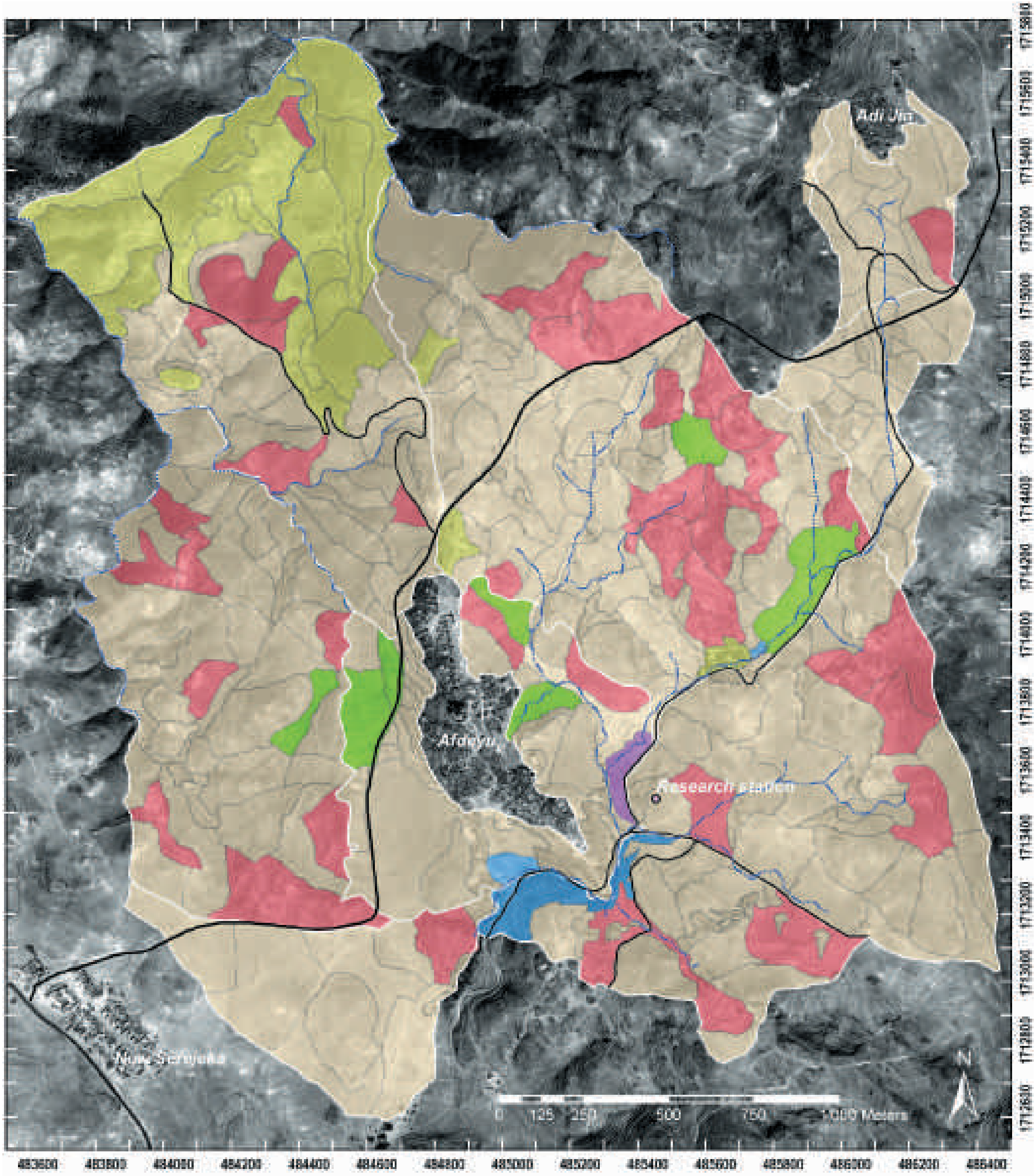
Water harvesting and water diversion structures: Micro-basins for tree planting – in association with hillside terraces – cover a large part of the afforestation area, especially where water availability is low. Their equivalent on cropland are the tied ridges, which were established on a large-scale basis and always in combination with bunds. Nowadays only remnants are left, predominantly in less intensively used areas or on uncultivated fields (e.g. steep slopes with shallow soils). On productive land nearly all tied ridges have been ploughed – especially in flat areas, where they can cause waterlogging and occupy fertile cropland.

Diversion bunds – combined with inlets (to fields) – are built along pathways, roads or natural water drainage lines to divert runoff to the productive areas. These water harvesting measures are often seasonal and thus not comprehensively documented on the maps. Depending on the local rainfall patterns and changing water availability, diversion structures require frequent management activities (opening them when rainfall is low, closing them during high intensity events). Therefore they are mainly applied in areas that are easily accessible, e.g. in Gedena and Grat Hamushte.

A small dam for water harvesting was constructed on a local initiative just above the sacred forest (Grat Hamushte, Afdeyu), but is now partly broken. The big earthen dam (reservoir) south of Afdeyu village was built in 1986 and collapsed the same year. A few irrigation plots on a small area facing the research station allow cultivation of vegetables. The water for bucket irrigation (in furrows) is taken from the nearby well.

Gully control: check dams control erosion hot spots such as gullies, pipe erosion or natural waterways, wherever concentrated runoff occurs. They are applied on all land use types. On cropland check dams are mostly applied punctually to treat specific spots affected by erosion (e.g. breached / collapsed terraces) – especially on fertile land – whereas they appear in series of up to 70 units in the pronounced valleys to the west of the study area (complementing bunds in an afforestation area). In contrast, the local measures for gully / pipe rehabilitation are exclusively established on individually owned cropland plots. Different methods were used for mapping check dams: single hotspots were recorded as GPS waypoints, whereas for series only the starting and end points may be mapped. In some cases the occurrence of check dams was attributed to an entire polygon.

Map 5 *(opposite page): Structural measures: water harvesting, water conservation →*



Structural measures (II)

Water harvesting/diversion

- No water harvest/div.
- Diversion bunds
- Tied ridges
- Micro-basins
- Water holes / small dams
- Furrow irrigation

Other features

- Streams
- Roads
- Village zone boundaries

Map information

Scale:	1:16,000
Raster resolution:	1 m
Grid interval (UTM):	100 m
Projection:	Universal Transverse Mercator (UTM)
UTM Zone:	UTMZ 37
Datum:	WGS-84

Data sources

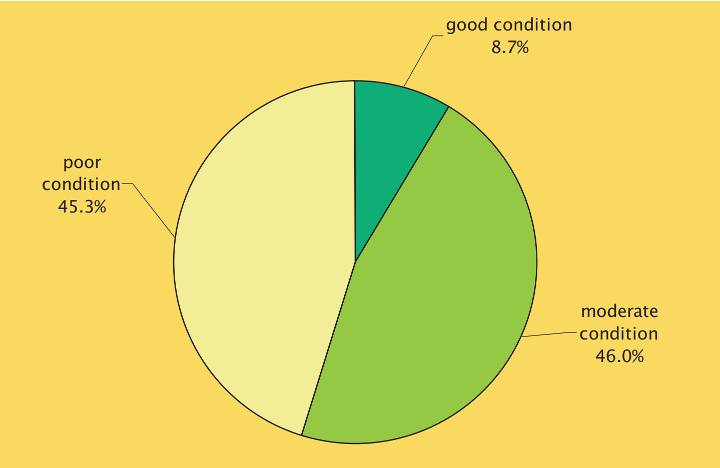
Satellite image:	GEOEYE 2000 (IKONOS II)
Land use types:	CDE/NARI Field survey 2004
Other feature data:	SLM Database 2004

Condition of SWC measures and land degradation

The condition of SWC measures is strongly related to the level of maintenance. The following classes have been used: Poor, moderate and good condition:

- Poor condition: Most measures are broken, have gaps, or have disappeared to a broad extent, no maintenance over the last years
- Moderate condition: Some gaps, slight siltation of ditches, etc.; all in all reasonable performance, maintenance activities carried out within the last 3 years
- Good condition: Good performance, no gaps, recently maintained or newly built

Note that the condition has been defined for the three most dominant measures in each polygon. As it is impossible to visualise all available information on the map, it now shows the average condition of the main (dominant) SWC measure applied in the respective polygon. The pattern shows that accessibility seems to influence the level of maintenance: measures situated close to settlements and roads tend to be in a better condition than those on the less accessible western slopes. However, one exception attracts attention: the afforestation area in the far northwest of the study area, where the tree component has been defined as the dominant measure. This means that the structural measures may be in a poor condition without it being reflected on the map (however, these data are included in the attribute table of the GIS). An overview of the entire study area is given in the table below:



Average condition of dominant measure	Area (ha)
Poor	242.58
Moderate	246.11
Good	46.36

Table 35 *(above): Average condition of SWC measures (in hectares). Only the dominant measure of each mapping unit (polygon) was considered in the calculation.*

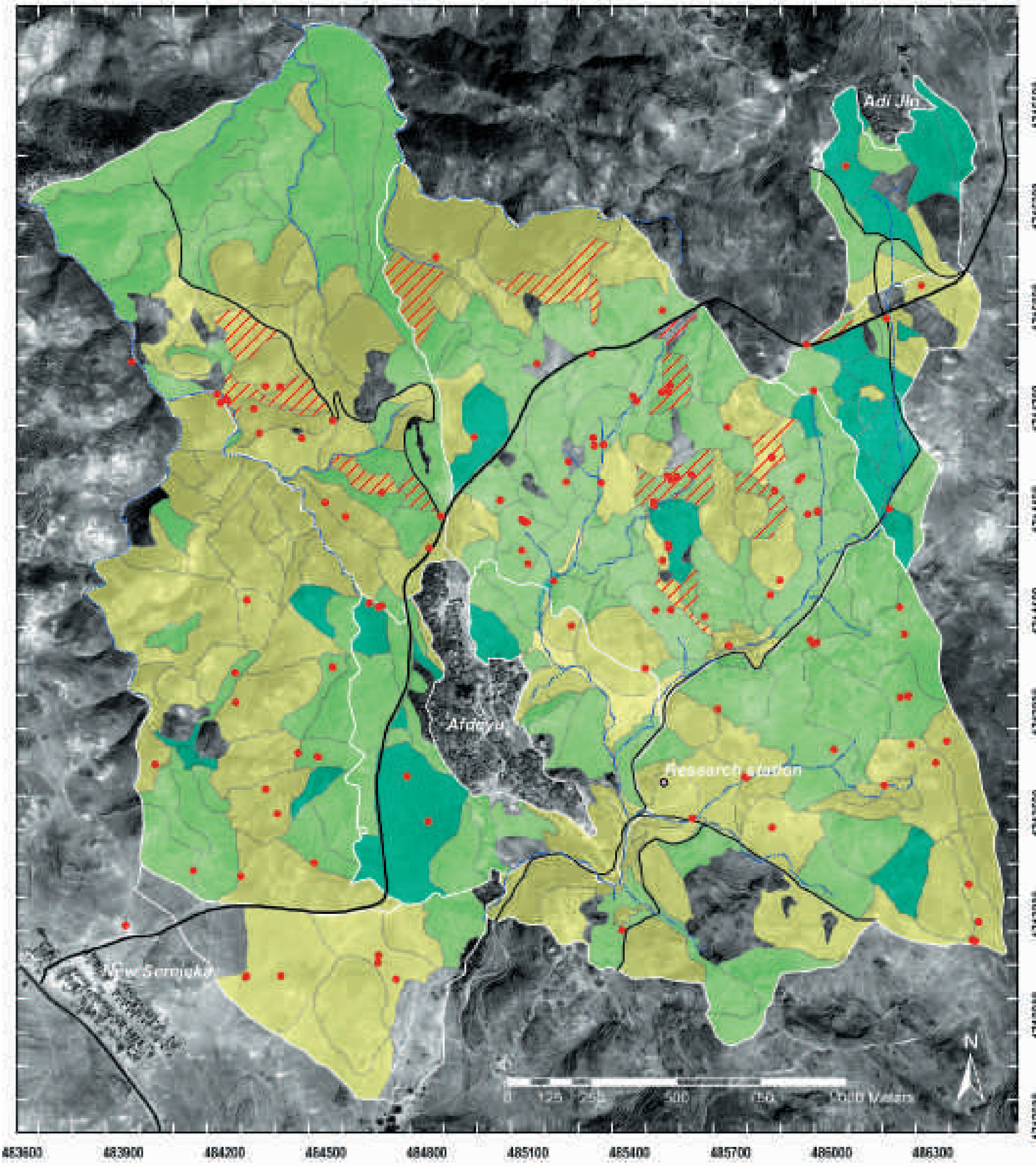
Figure 16 *(left): Average condition of SWC measures (in percentage)*

Erosion hotspots

Hotspots are defined as sites that are prone to, or already affected by, soil erosion / degradation, including damaged SWC structures, gullies, pipe erosion, etc.

Around 50% of all hotspots are located on poor-fertility land, and likewise around 50% of the hotspots appear in areas where SWC measures are in a poor condition. This confirms the trends mentioned above. Hotspots on fertile land are mainly located in natural drainage lines (e.g. in the flat valley bottoms of Grat Hamushte), where, on the one hand, fertile soil is accumulated, but on the other hand, runoff can cause damage to existing SWC structures during high intensity rainfall events. Note that the recording of hotspots is not complete.

Map 6 *(opposite page): Condition of SWC measures and erosion hotspots →*



SWC Conditions

- Poor condition
- Moderate condition
- Good condition
- No information
- Degraded areas
- Hotspots

Other features

- Streams
- Roads
- Village zone boundaries

Map information

Scale:	1:16,000
Raster resolution:	1 m
Grid interval (UTM):	100 m
Projection:	Universal Transverse Mercator (UTM)
UTM Zone:	UTMZ 37
Datum:	WGS-84

Data sources

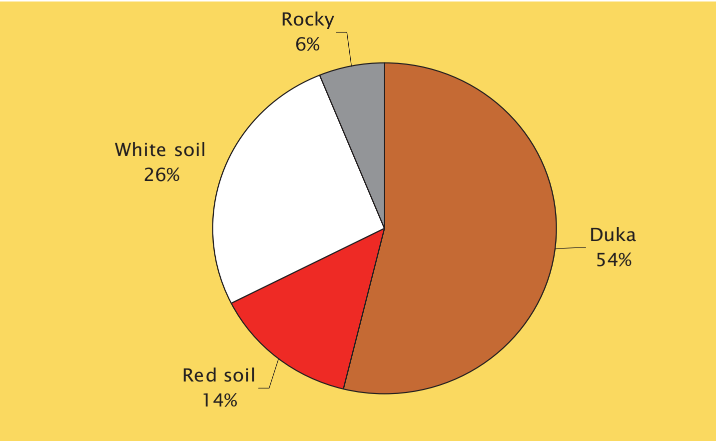
Satellite image:	GEOEYE 2000 (IKONOS II)
Land use types:	CDE/NARI Field survey 2004
Other feature data:	SLM Database 2004

Soil types

The most frequent soil type is *duka*: it covers about 54% of the study area. Overlaying the soil type layer with the topographic layer reveals that *duka* tends to occur more often in flat areas, along waterways and on terraced slopes (e.g. bench terraces near settlements). It seems that these soils predominantly develop in areas where accumulation takes place and erosion processes are less pronounced.

White soils are more frequent in remote and less intensively used areas where inputs are low, e.g. on hilltops or on the western slopes. At the same time, these areas are often affected by erosion.

The distribution of red soils over the study area is relatively uniform, making it impossible to draw any conclusions from the map, apart from the fact that they often occur on slopes. Likewise, small spots of rocky outcrops and very shallow stony soils are scattered throughout the area without any specific pattern.



Soil type	Area (ha)
Duka	308.94
Red soil	77.48
White soil	151.50
Rocky	35.19

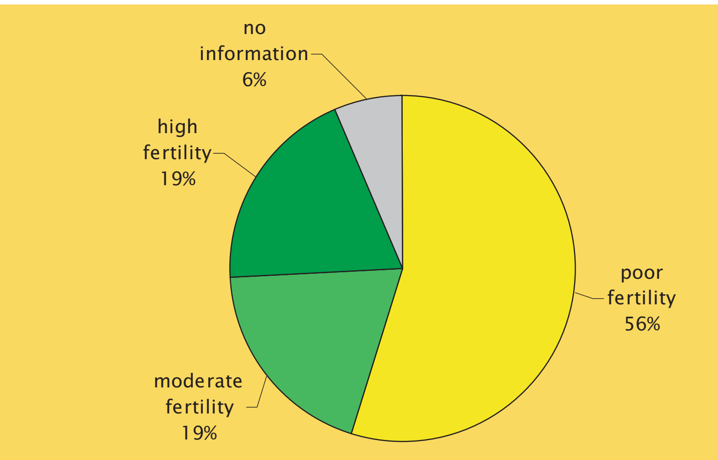
Table 36 *(above): Area coverage of local soil types (in hectares)*

Figure 17 *(left): Area coverage of local soil types (in percentage)*

Soil fertility

In the area northwest of the new road most polygons are classified as low fertility. Slopes are steep, measures are less well-maintained, erosion rates probably higher, and cultivation less intensive or altogether impossible (stony shallow soils, enclosures for afforestation). There is one exception where fertility is high, down in a steep valley in the north of the study area. Farmers explain that this is an area that has not been used for long time and where the special dark type of *duka* (*bodu*, see page 130) occurs. All in all, more than half of the study area is characterised by poor soils.

Fertile areas are concentrated around the villages, on the intensively used and conserved Gedena land, as well as on the flat or gently sloping valley bottoms (e.g. in Grat Hamushte), where fertile topsoil is accumulated.

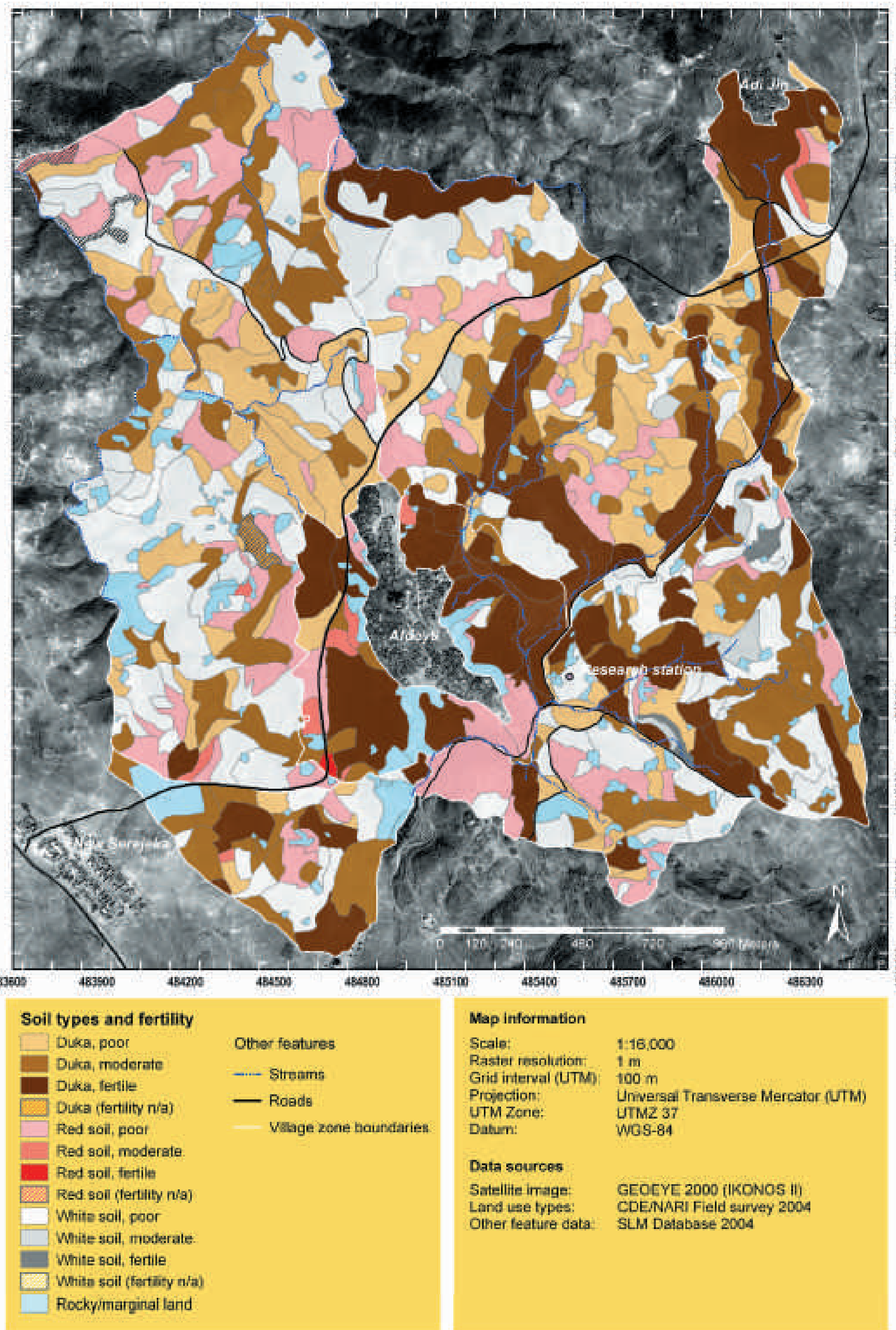


Fertility	Area (ha)
Poor	313.94
Moderate	111.88
High	111.37
No information	37.11

Table 37 *(above): Area coverage of local soil fertility classes (in hectares)*

Figure 18 *Area coverage of local soil fertility classes (in percentage)*

Map 7 *(opposite page): Soil types and soil fertility →*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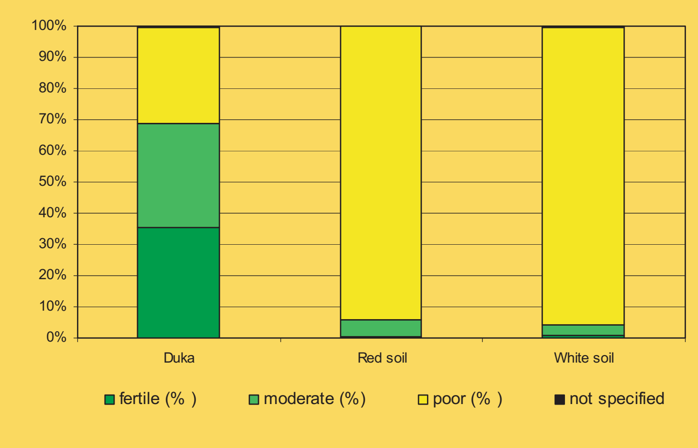
1714100
1714400
1714700
1715000
1715300
1715600
0 120 240 480 720 960 Meters
N
Soil types and fertility
Duka, poor
Duka, moderate
Duka, fertile
Duka (fertility n/a)
Red soil, poor
Red soil, moderate
Red soil, fertile
Red soil (fertility n/a)
White soil, poor
White soil, moderate
White soil, fertile
White soil (fertility n/a)
Rocky/marginal land
Other features
Streams
Roads
Village zone boundaries
Map information
Scale: 1:16,000
Raster resolution: 1 m
Grid interval (UTM): 100 m
Projection: Universal Transverse Mercator (UTM)
UTM Zone: UTMZ 37
Datum: WGS-84
Data sources
Satellite image: GEOEYE 2000 (IKONOS II)
Land use types: CDE/NARI Field survey 2004
Other feature data: SLM Database 2004

Overlaying soil types and soil fertility



	Duka	Red soil	White soil
fertile (%)	35.4	0.5	1.0
moderate (%)	33.3	5.5	3.0
poor (%)	30.9	94.0	95.4
not specified	0.3	0.0	0.6
	100	100	100

Table 38 *(above): Soil fertility classes within different soil types (in percentage)*

Figure 19 *(left): Soil fertility classes within different soil types (in percentage)*

When topography, waterways, soil type and soil fertility are combined in a map, what catches the eye is that fertile *duka* occurs almost exclusively along and around riverbeds, in flat areas and on Gedena land which has been terraced for generations. This supports the assumption that soil development and soil fertility are influenced by soil accumulation. This hypothesis is also supported by the observation made in one soil profile at a depth of more than 3 m: below the actual soil profile a black soil horizon was found, looking like an ancient vertisol (not scientifically analysed). These fertile *duka* soils are high potential areas for crop cultivation and cover just less than 20% of the study area. The statistical analysis of the two overlaid maps impressively confirms the local assessment of soil types and fertility: *duka* is by far the most fertile type, while white and red soils are classified as poor on 96% and 94% of their total area, respectively.

Overlaying condition of SWC measures and soil fertility

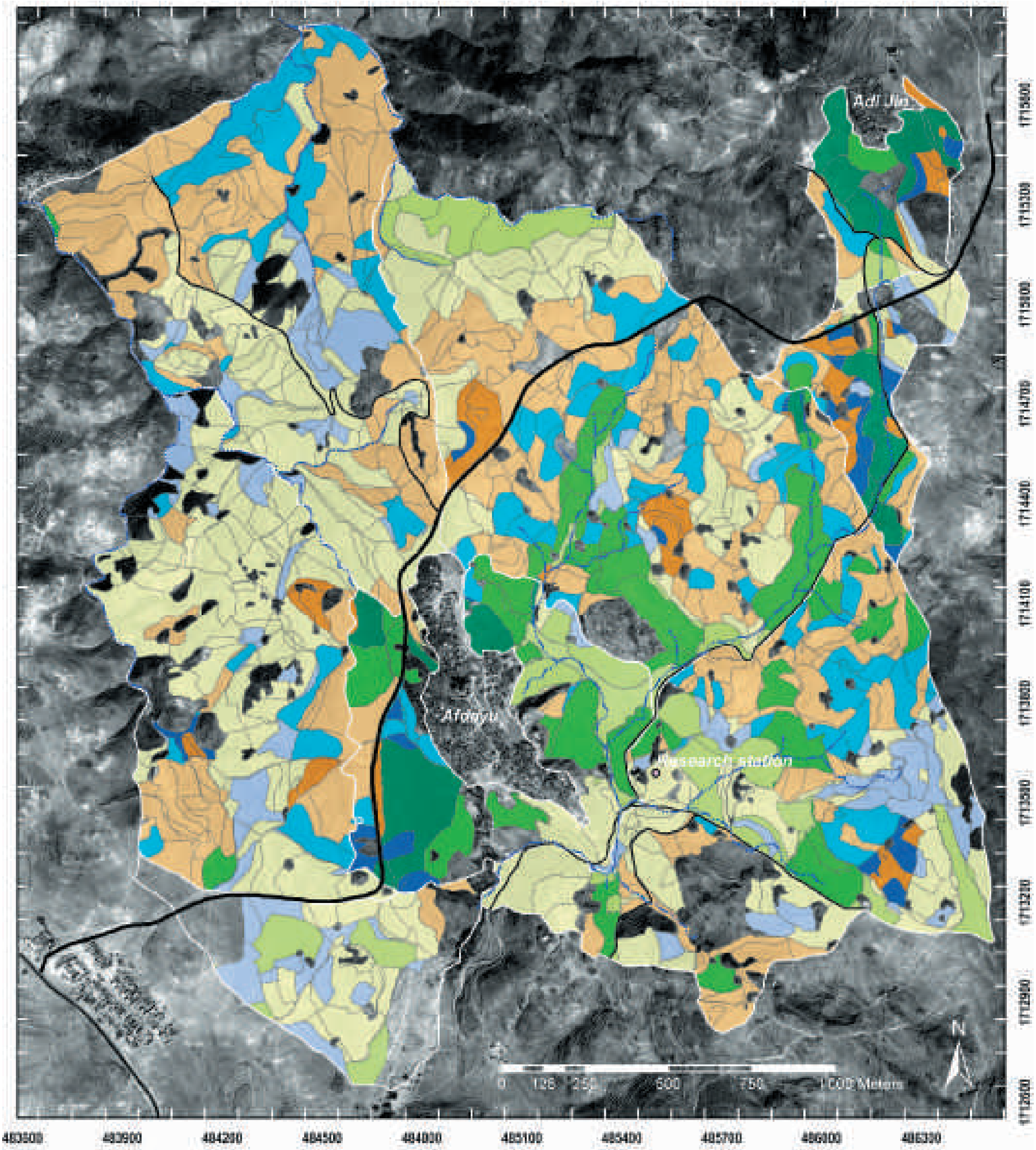
Accessibility is one factor that may be influencing the maintenance of SWC measures. As indicated before, the fertility of a field is another important variable. In order to analyse the correlation between the fertility class of a plot and the condition of the measures applied on it, the two layers have been overlaid. The results are presented in the following table:

Table 39: *Correlation of soil fertility classes and condition of SWC measures*

SWC in poor condition		SWC in moderate condition		SWC in good condition	
Fertility class	Area coverage	Fertility class	Area coverage	Fertility class	Area coverage
poor	63%	poor	54%	poor	30%
moderate	16%	moderate	22%	moderate	19%
high	14%	high	19%	high	49%
no information	7%	no information	5%	no information	2%

Of the total area with measures in a poor condition, 63% are also characterised by poor fertility, while only 14% are located on high-fertility land. For areas where measures are in a moderate condition, the picture is similar, with a slight shift towards more fertile areas. The situation radically changes when looking at the land where SWC measures are still intact: here, almost half of the area is fertile, and less than a third is of poor fertility. This shows a clear interrelation: the higher a field's fertility and thus its expected yields, the more farmers invest into maintenance of SWC measures.

Map 8 *(opposite page): Condition of SWC measures and soil fertility →*



Overlay of soil fertility and condition of SWC measures

- n/a
- Low fertility, poor condition
- Low fertility, mod. condition
- Low fertility, good condition
- Mod. fertility, poor condition
- Mod. fertility, mod. condition
- Mod. fertility, good condition
- High fertility, poor condition
- High fertility, mod. condition
- High fertility, goodcondition

Other features

- Streams
- Roads
- Village zone boundaries

Map information

Scale:	1:16,000
Raster resolution:	1 m
Grid interval (UTM):	100 m
Projection:	Univ. Transverse Mercator (UTM)
UTM Zone:	UTMZ 37
Datum:	WGS-84

Data sources

Satellite image:	GEOEYE 2000 (IKONOS II)
Land use types:	CDE/NARI Field survey 2004
Other feature data:	SLM Database 2004

Conclusions and recommendations

Conclusions on SWC measures

SWC measures in the study area are exposed to extreme conditions: steep slopes – bare and uncovered by vegetation at the onset of the rainy season – constitute a great challenge, long dry periods require measures that promote water and moisture conservation, and, at the same time, intensive rainstorms demand massive structural SWC (to ensure retention of runoff and safe drainage of excess water). All these factors have to be considered when designing and implementing SWC measures.

Great diversity of SWC measures

An astonishing diversity of local and introduced SWC measures has been identified in the study area. In total, 24 measures were identified and described. Out of these, 13 are local measures and 10 introduced (externally promoted). They often occur in complex combinations in the field. Structural, agronomic and vegetative measures complement each other. A total of 11 structural, 7 agronomic and 5 vegetative measures have been identified; two of the vegetative measures (afforestation and area closure) include a change of management and thus could be classified also as management measures.

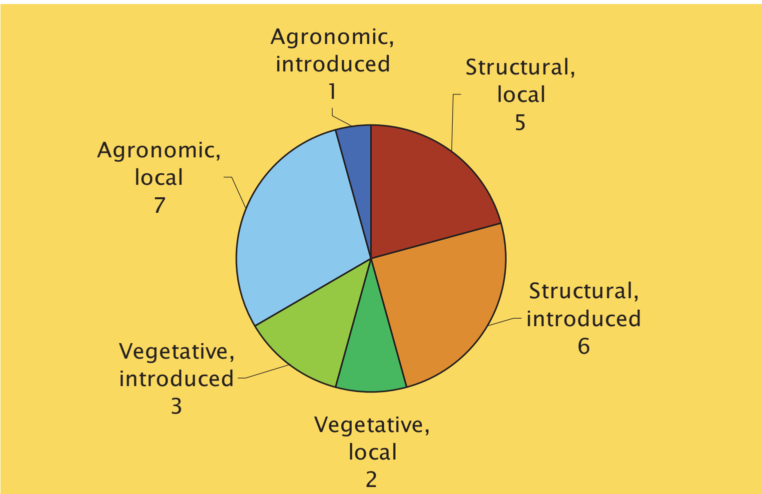


Figure 20: *Number of measures in different SWC categories (100% = 23 measures).*

Focus on cropland

SWC in general, and local measures in particular, focus on cropland: 77% of all measures are applied to cropland (12 local / 8 introduced), 19% to forest land (1 local / 4 introduced) and only 4% to grazing land (introduced). Note that several measures, such as check dams, are applied to more than one land use category. This distribution reflects the land use coverage (cropland covers 70% of the study area) and underlines the importance of crop production (base of livelihoods in the area).

Measures in the forest area are mainly introduced, since these enclosures were to a large extent established on external initiative (afforestation programme). Furthermore, these areas are communal, and in the absence of individual land use rights, nobody feels responsible for the maintenance of SWC measures.

Designated grazing land is very scarce and uncontrolled grazing is practiced on cropland (after harvest) which can cause severe damage to structural measures.

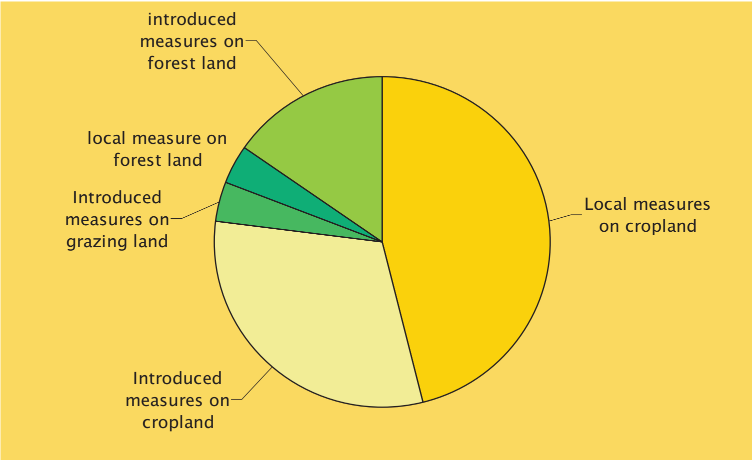


Figure 21: Number of SWC measures associated with the different land use types.

Focus on structural and agronomic measures

Vegetative measures are almost non-existent. There were only five vegetative measures identified and for all of them, area coverage is extremely low, except for afforestation/enclosure.

SWC on cropland emphasises agronomic and structural measures. Directly depending on agricultural production, fertility management becomes a priority in subsistence farming! Many local measures focus on sustaining or improving productivity (yields) whereby not only soil fertility but also water availability is crucial. These measures are often not primarily perceived as SWC measures. The potential of a given technology to maintain or increase yields is a major aspect determining its acceptance.

Local versus introduced SWC measures

Local SWC measures are the result of a gradual learning process over generations, based on constant observation and experimentation, and are therefore continually adapted to changing ecological and socio-economic circumstances and to farmers' needs. They are based mainly on inputs available on the farm (low external input systems), and appear as integrated part of the local farming system. All these aspects contribute to a high level of acceptance, resulting in spontaneous adoption / replication: nine out of the ten best accepted measures are local!

However, farmers are open towards introduced measures, provided that they are adapted (or adaptable) to their needs and local conditions (environment, available resources and knowledge). The successful example of introduced stone and earth bunds provides an impressive confirmation of this fact. Introduced measures are particularly important on forestland and on marginal, unproductive areas. The case of tied ridges – a measure that disappeared as fast as it was implemented – underlines the fact that the application of any technology has to be site-specific and must consider local knowledge and needs. As a result of the approaches used to implement introduced measures, they tend to be applied at a larger scale than local measures, which is considered a big advantage.

Often, there is a smooth transition between introduced and local measures. Measures that were originally introduced go through a process of replication, modification and adaptation, are adopted and integrated into the prevailing land use system, and are finally considered indigenous. On the other hand, in some cases the uniform implementation of introduced measures implicates a lack of site-specific solutions.

Table 40 on page 166 summarises and compares the characteristics of local and introduced SWC measures.

Table 40: Summarised characteristics of local and introduced SWC measures

Characteristics	Local SWC measures	External / introduced SWC measures
Design	By local farmers	By engineers, development planners
Purpose	Multiple purposes (multi-functional), depending on setting; often fertility management and water harvesting	Soil and water conservation
Design features	Flexible, subject to modifications, site-specific, and adapted to local (and seasonal) variation of biophysical and socio-economic factors; seasonal, semi-permanent or permanent	Fixed, standardised, homogeneous design, applied at a large scale; permanent
Area of application	Cropland	Uncultivated hillsides (afforestation areas, grazing land, marginal land), cropland
Implementation	Incremental, integrated in existing farming system, in accordance with household labour availability, individual	One-time, collective campaign work; separate activity (isolated, not integrated in farming system) causing extra costs
Approach	Innovation by farmers, farmer-to-farmer extension, spontaneous adoption, no external support or assistance	Large-scale campaigns providing incentives such as food-for-work or cash-for-work (employment-based) and technical assistance
Labour input	Variable, generally low	High
Inputs and costs	Resources available on farm, low-external-input system, low-cost technology	Can involve considerable external inputs, e.g. fertilisers, high costs
Returns	Mostly short-term	Often mid- / long-term

High area coverage

Generally speaking, area coverage of SWC measures is high: almost 95% of the cropland in the study area is 'treated' with SWC measures. However, differences between measures are huge: certain structural measures (such as stone terraces and contour bunds) and agronomic measures (such as compost application, local ploughing system and fallowing) have spread almost over the whole cropping area, whereas vegetative measures (e.g. grass strips and trees on cropland) but also other measures (e.g. tied ridges) are extremely rare. Introduced measures contribute a lot to area coverage since, contrary to local measures, they extend into marginal, unproductive areas.

Lack of maintenance

Regarding quality, the condition of the measures in place is often insufficient (basically referring to structural measures). This is mainly due to lack of maintenance. Again, there is a high spatial variability (see map). Principally, farmers are aware of the importance of SWC and the benefits to be gained in terms of increased productivity. They recognise the need to maintain them, but a range of limitations is hindering investments in conservation activities:

Main limitations of SWC

- Importance of off-farm income/activities (less time spent on the field)
- Lack of (material) incentives
- Lack of manpower
- Attitude (individual perception, commitment)
- Insecure land use rights (*diessa* system)
- Land shortage

In principle, most of these aspects are referring to limited financial, human and natural resources and various of these factors are interrelated. Off-farm income, incentives and the issue of land security are important aspects with regard to SWC measures that lack short-term benefits (labour-intensive structures, tree planting, etc). In view of the limited resources, farmers are forced to concentrate investments on high potential areas, such as the intensively used areas around the settlements (Gedena) and flat, fertile areas with sufficient water availability.

Maintenance is most problematic

- in case of highly labour-intensive measures;
- on land other than cropland / on communal land: absence of individual land use rights / benefits discourages farmers to maintain these areas
- on marginal land: low fertility or accessibility hinders investments in SWC.

Best average conditions are stated for boundary soil bunds (stabilised by grass cover, never ploughed) and afforestation / permanent area closures (here, the condition is referring to the trees), both measures that do not require special maintenance activities. They are followed by the main structures **on cropland** (diversion bunds/furrows, stone and earth bunds, check dams, stone terraces). Grass strips and tied ridges again appear at the end of the list.

Acceptance of SWC measures: a key to sustainable land use

Measures that are not accepted are the first to lack maintenance. Consequently, they quickly lose their effectiveness and functionality. This leads to a vicious circle: the less SWC structures are maintained, the more degradation processes aggravate and the more the quality / productivity of the land declines. Thus, acceptance is a key to sustainable land use.

Table 41: Best and least accepted SWC measures

Best accepted of all SWC measures	Least accepted of all SWC measures
1. Manure / compost application	1. Agroforestry
2. Fallowing	2. Tied ridges
3. Crop rotation	3. Stone mulching
4. Local ploughing system	4. Live fences
5. Fertiliser application	5. Grass strips

Key factors of acceptability

There are many factors that have an influence on acceptance. To encourage acceptance, a SWC measure should:

- increase production
- efficiently conserve natural resources
- be cheap / cost-effective: require low external input
- minimise risk (e.g. of production failure; or with regard to additional risks created by the measure itself)
- be flexible and adaptable (according to individual preferences and needs)
- involve local knowledge

Perhaps the two most important factors regarding acceptability are for the measure in question to be:

- adapted to the local conditions, available labour, inputs and knowledge, and to local needs
- maintainable and replicable without external support

Agronomic measures: The study has shown that agronomic measures are generally best accepted. They fulfil a range of prerequisites that are crucial to the land users and thus favour acceptability.

- don't cause loss of productive area
- don't require high external inputs
- are not labour-intensive
- are often local
- are well-integrated in farming activities
- are production-oriented (increase/maintain yields)
- are often not considered SWC measures by farmers

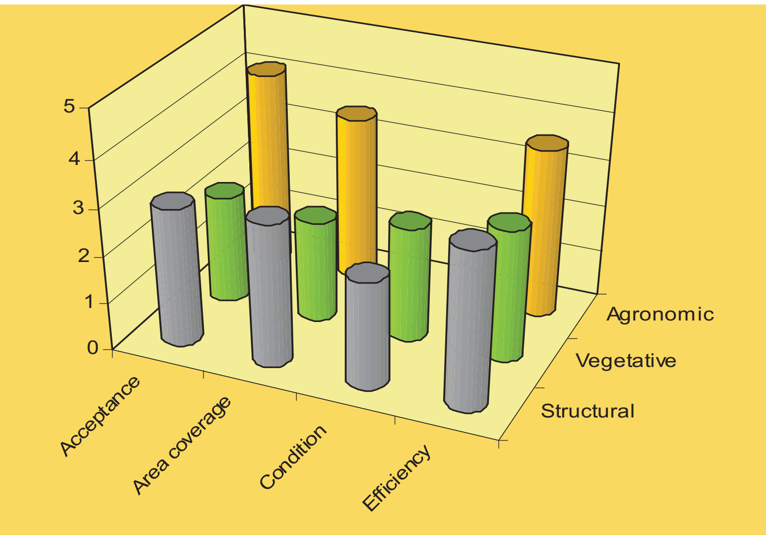


Figure 22: *Comparison of acceptance, area cover, condition and efficiency between different measures*

Structural measures face limitations regarding labour (high input needed) and short-term returns (lack of direct economical benefits). Thus, the inhibition threshold for investments is higher, especially regarding the temporally limited land use rights. Nevertheless, they have several crucial functions: 1) they allow to turn steep slopes into arable land, which is essential in this area; 2) they effectively reduce erosion and rehabilitate areas affected by gullies; 3) they increase water availability. That is why stone terraces and stone and earth bunds, both local and introduced, are widespread and highly accepted.

Vegetative measures, such as agroforestry or grass strips – which are needed to improve soil cover and availability of fodder / wood – have a very low acceptance in the community. Farmers associate several negative effects with trees on cropland: trees are a habitat for birds which affect crops, they compete with crops for nutrients and light, benefits are only obtained on long term and open grazing makes plantation of seedlings difficult.

Impressive local knowledge

Some farmers have gathered a lot of experience through experimentation and participation in trainings; they have an in-depth know-how on SWC measures and their effects, but also on soils, their suitability for crops, degradation processes and other relevant aspect of the natural environment. This wealth of local knowledge is not sufficiently involved in planning, implementation and evaluation of SWC measures. Appropriate tools to integrate local knowledge are missing.

Recommendations on SWC measures

Agronomic measures: focus on productivity

Agronomic measures such as improved manure production (with addition of chemical fertilisers) and introduction of irrigation methods (e.g. drip irrigation, deficit irrigation) should be promoted: They have a high potential to increase productivity and thus to increase food security and reduced dependence on variability of rainfalls. Variety testing of various highland crops could further contribute to boost yields. Irrigation would also allow to extend the production of cash-crops, and thus help generate much needed income. Intercropping and crop rotation, being local and accepted measures, can be further developed. Finally, minimum tillage should be considered as an option for SWC, since it has proven in many countries to be a cheap and effective technology, both protecting the soil, conserving moisture and increasing production.

Structural measures: focus on 'hazardous areas'

Covering most of the area already, structural measures in the future should focus on site-specific improvements such as:

- maintenance of existing measures (siltation, gaps)
- the treatment of degradation 'hotspots', such as gullies, collapsed terraces, pipe erosion
- highly erosion-prone areas, e.g. reinforce/stabilise waterways for drainage of excess water where high runoff occurs during rainy season, combining structural and vegetative measures

***Photo 36**: Runoff after a heavy rainfall indicates where investments are needed: Implementation and maintenance of structural measures have to focus on highly erosion-prone areas (hotspots).*

Vegetative measures: focus on multipurpose species

Methods of improved fodder production play an central role in solving the grazing land problem.

Promotion of dual purpose grasses (SWC / fodder) is recommended, e.g. test palatable and drought resistant species on contour bunds; introduce legume lays on fallowed land, in closed areas. Measures have to be combined with improved grazing practices (see below).

Further tree planting has to be encouraged, also to provide fuelwood and thus make dung available for composting. Activities could include on-farm trials with multipurpose trees (nitrogen-fixing, fruit, timber, fuelwood, fodder…). Also, the management and user rights of existing afforestation areas should be improved, including economically attractive entitlements for local households.

Management measures: focus on grazing land

Farmers need to be encouraged to adopt new practices regarding grazing land management: e.g. controlled grazing and/or cut-and-carry (see also vegetative measures for fodder production). Such measures would considerably increase the availability of manure (to be used as fertiliser) and protect SWC from trampling by cattle.

General recommendations

Application of measures needs to be site-specific (e.g. flat/steep slopes): there is no technology which can be applied uniformly at the catchment level; application always needs to be adapted to the local ecological and socio-economic conditions, to individual needs (subjective criteria, personal interest), and to local knowledge! Priority areas should be identified according to farmers' needs.

Farmers need to be given the opportunity to experiment with newly introduced measures, gain experience, and adapt them to their situation and needs.

Photo 37: *Farmers load eucalyptus logs for sale on a truck. Income generation is a central issue regarding integrated approaches.*

Photo 38: *Irrigation is practised on a very small area in the study area and holds much potential for improving the living conditions of the local population.*

Conclusions on SWC approaches

There is a wealth of local knowledge, but tools or platforms are missing to pick it up and integrate it into planning, research and implementation of SWC.

There are basically two relevant approaches in the area:

- externally promoted, incentive-driven mass campaigns (introduced)
- individual initiative on local level

The pros and cons of CFW/FFW Campaigns (farmers' perception)

Farmers consider campaigns as a good approach, providing multiple benefits, though various weaknesses of this approach are recognised:

***Table 42**: Pros and cons of CFW/FFW approaches*

Pros	Cons
+ Important source of income + Increase productivity through SWC + Covers uncultivated, marginal land + Covers communal land as well + Covers land of disabled or unaware land users: Vulnerable households benefit from community participation → Uniform protection of all areas (catchment level)	– Decisions on choice of technology, area of application, etc. taken without consultation of land users; local knowledge, preferences and needs are not sufficiently involved – Uniform application of SWC measures, ignoring ecological and socio-economic diversity, not adapted to site-specific (local) conditions – Incentive-driven implementation: farmers consider SWC a separate activity which they are paid for; expectation that incentives should also be provided for maintenance

Planning: where participation starts

An active participation of the local land users in planning and the involvement of local knowledge in particular are a prerequisite for acceptance of SWC measures.

Extensionists have a crucial role as facilitators of change and communicators between farmers, researchers, project implementers and policy makers. Awareness-raising and training activities are important to improve understanding of the functioning of planned SWC measures and let new ideas become rooted in the community. In this process, mutual learning processes (e.g. participatory technology development – PTD) have a great potential.

The importance of evaluation and monitoring

Monitoring is essential to assess the condition, effectiveness, and acceptance of SWC measures. So far, monitoring of SWC activities has focused on achievement in terms of coverage (quantitative indicators). Quality and impact assessment (based on farmers perception) has not been part of monitoring activities. Monitoring data is not documented and not available.

Recommendations on SWC approaches

Planning: involving all stakeholders

Communication and sharing of ideas among farmers, extension workers and researchers needs to be improved. The use of means and platforms of communication which are appropriate for all stakeholders is essential.

Regular participatory planning meetings should be conducted to involve farmers' needs and knowledge and to formulate research and implementation proposals.

Learning from monitoring and evaluation

Monitoring and evaluation activities need to be enhanced: Assessments of the condition and impacts of SWC measures *after* implementation should complement the quantitative progress reports on established measures. Monitoring and evaluation should involve farmers, the Afdeyu research sub-station, and stakeholders from the MoA and the university.

As a result of monitoring activities, 'lessons learnt' should be drawn up and serve as a basis for need-driven planning of further activities.

Research: making use of existing local knowledge

On-farm trials to test and demonstrate innovations should be promoted to increase knowledge, raise awareness of benefits, and improve acceptance of SWC measures. Participatory technology development helps involve the wealth of local knowledge. Based on a selection of the most promising local measures (or generally the best accepted measures), improvements can be negotiated between researchers and farmers. Involvement of all stakeholders (farmers, research- and development-assistants, local / regional advisers, extensionists etc.) in the development of research activities helps increase the responsibility of each of them. Special efforts are needed to link research with extension and the local land users, and to facilitate the flow of information in both directions.

Extension / training

Training of enumerators (trainers) in the communities needs to be promoted: these local experts play a key role in knowledge transfer regarding SWC. Building up on local expertise and human capital and strengthening farmer-to-farmer extension is a promising approach.

Simultaneously, additional training and technical manuals designed for extension workers (containing technical specifications and steps of implementation of SWC measures) are needed to improve extension activities. To strengthen the link between extension agents and the community, a responsible extension agent should be assigned for each *kebabi* (2–3 villages).

Decentralised and institutionalised ways of exchanging ideas and needs between farmers and extension workers are required, e.g. regular meetings with representatives of village development committees (enumerators).

Finally, the dissemination of the outputs of research to the end users should be achieved, e.g. by establishing various means of communication such as study reports / leaflets; field demonstrations and farmers' field schools; farmer-to-farmer exchange visits; broadcasting research findings via mass media in a local language, etc.

Economic issues

Improved irrigation facilities are important to promote the cultivation of cash crops (such as vegetables) which would help to overcome financial problems (see Stillhardt, Ghebru, Mehari Haile 2003). Also, tree plantation – with individual user rights – provides much needed income to farmers and should be further encouraged.

The establishment of a credit system, e.g. revolving funds or micro-credit systems, would help poor land users to defeat financial difficulties. In view of the limited land resources, the promotion of alternative opportunities for income generation is of great importance, e.g. food processing, handicrafts, carpentry, poultry farms. This is a step in direction of a more integrated approach which does not focus on agriculture alone.

Policy

Adaptation of rules and regulations concerning land ownership is recommendable: long-term user rights allow long-term planning and investments. The traditional land tenure system aims to be egalitarian but leads to fragmentation of land. Challenge in the future is how this will affect SWC, and agricultural productivity. Farmers propose to establish a reward system for good maintenance.

Within the given context, a better integration of land users (and their needs and knowledge) through active participation in all phases (planning, research, implementation, evaluation) might be the key to raising the acceptance of SWC measures and thus improve maintenance without providing incentives.

Photo 39: *Participatory planning: involvement of local farmers, extensionists, researchers and decision-makers.*

Photo 40: *Working with key informants and making use of local knowledge: mapping of SWC measures and their condition.*

Conclusions and recommendations regarding soils

Soil classification

The attribution of soil properties to local names is rather consistent throughout all studies presented in the soil section, and the attribution of local soil names to the FAO classification in the different studies correlates fairly well. This means that in the above-described area (central highlands and southern midlands of Eritrea) it will be possible to assess soil properties more rapidly in future, as farmers' statements can now, on the basis of these various studies (including the one in hand), to a large extent be "translated" to scientifically understandable outputs such as FAO soil types. Of course, the accuracy of results will never be as high as in a scientific soil analysis, but indications on soil fertility, depth, water storage, stoniness, slope gradient and other parameters obtained on the basis of local soil classification are nonetheless of a good enough quality for most planning purposes. The authors therefore recommend that the present assessment be further completed by an in-depth study and adapted for use in decision-making and policy-making.

Assessment of structure and texture in the local classification is based mainly on criteria influencing soil workability, whereas in the FAO classification, it refers to the size and weight of the soil's inorganic particles. Results can therefore slightly differ, especially if none of the components are clearly dominating.

Comparison with the local classification is difficult where characteristics of the B- or C-horizon are important criteria in the FAO classification (e.g. for luvisols), since the local classification depends mainly on characteristics of the A-horizon.

Soil fertility

Soil fertility is one of the most important criteria in local soil classification systems. The concept behind the scientific definition of soil fertility and the local assessments is rather different. Scientific measurements are based on the availability of macro- and micro-nutrients whereas for farmers, soil fertility is the sum of factors leading to a good (high) yield. Depending on the area, this approach includes temperature, rainfall amount, rainfall distribution, water holding capacity, soil depth, response to manure, workability, etc.

The results of soil fertility assessment based on the local classification and those based on the FAO classification correspond well. This implies that in future studies, an appraisal with the local classification should lead to good results. It is possible for soil scientists to make preliminary conclusions and to plan agricultural interventions based on information obtained from farmers.

The analogy between the different local assessments is high:

- *Duka* is normally classified as the most fertile soil in the area, suitable to grow all crops.
- *Walaka* is of the same high fertility as *duka* but is of limited use for crop growing because of its physical properties: high content in clay, forming deep cracks when drying out, hard when dry, sticky when too wet.
- *Keih hamed* is classified as low to medium fertile.
- *Hutsa* (sand); is classified as medium fertile. It does not occur in the study area.
- White soils and *Ba'akel* are classified as the least fertile soil type in the area in all farmers' assessments. This is surprising, since in a scientific attribution to the FAO soil classification (by Semere Zaid and RELMA) they were attributed to cambisol or luvisol, the same as *duka*. It is recommended to further study *Ba'akel*-soils and compare additional results with the FAO classification in order to better harmonise the two approaches. (The map on soil types of the Afdeyu area can be used to define further sampling sites for additional testing of *Ba'akel*.)

Use of the study results and the soil map

The results of the comparison of the local and the scientific classifications provide a tool for better communication between farmers and scientists and allow better and easier understanding of different stakeholders in participatory approaches.

Intensification of the land use system requires extension of intensive land use into less favourable areas. These additional intensively used areas should be selected according to the soil fertility map – and special care should be given to these areas in order to maintain or even increase their soil fertility. As is often said and is also visible in the soil fertility map, nowadays there is a correlation between soil fertility and distance from the village, because the areas next to the villages (Gedena) receive a more intensive treatment. It is recommended to select additional high-potential areas for land use intensification and – simultaneously – for enhancing SWC activities according to the soil map.

Traditionally there is a highly sophisticated system of strategies to minimise risks by using different locally adapted crop varieties. It is recommended to systematically study local knowledge about crop varieties, their advantages, and specific needs, and to add scientific knowledge about properties of improved varieties (NARI, colleges). By combining the information in a participatory process, a set of best practices could be developed, based also on the available information about soil types, slopes, stoniness and other relevant parameters.

More intensive use of the land resources requires more input to maintain soil fertility. Since fertiliser is expensive and difficult to find, it is recommended to apply the available fertiliser on high-potential areas where the soil responds best.

Photo 41: *Siltation of eroded fertile topsoil on a terrace bed: Degradation processes and conservation measures have impacts on the quality of the soil.*

Summary of final stakeholder workshop and outlook

Workshop programme, participants and objectives

In December 2005, farmers of the study areas and representatives from different governmental and non-governmental institutions were invited to participate in an international stakeholder workshop. A list of the 118 participants can be found in "References" (page 185 et sqq.). The workshop was carried out at Afdeyu research station and had the following objectives:

1. To present and discuss the research findings from the participatory appraisal of conservation measures and soils and to give plausible recommendations
2. To identify starting points for more participatory and more demand-driven SWC activities

The programme consisted of two parts: In the morning, the results of the study were presented to scientists, implementers and farmers. In the afternoon, the participants were divided into three working groups of about 25 persons – comprising representatives of all stakeholder groups, men and women. Each working group discussed a specific core topic (see below), came up with concrete proposals for next steps, and presented their findings to the plenary. Each presentation was followed by a short plenary discussion. Due to the limited time frame, the members of the different working groups did not reach consensus on all proposals made.

Outcome of working groups

Working group 1

Theme 1: What kind of institutional and organisational setup is needed to realise applied and demand-driven research and implementation in a participatory way, including all stakeholders?

Stakeholders: farmers, local administration, village organisations, local offices of MoA, MoA, NARI, the University, involved national and international NGO's.

1. Which organisations / institutions have to be included into the process of planning and implementation?
2. What are the tasks of the different stakeholder groups involved?
3. How can communication be improved and secured between the stakeholder groups?
4. What (initial) steps (methods, tools) need to be taken in order to establish a "network"?

Results of working group 1

Relating to questions 1 and 2, the working group proposes the following solutions:

***Table 43**: The tasks of the different stakeholders as identified during group work*

Stakeholder	Tasks
Ministry of Agriculture at all levels	Planning and implementation Provision of technical support Monitoring and evaluation
Ministry of Land, Water, and Environment	Development of solutions for the land tenure system Provision of information regarding water management Environmental impact assessment
Research (MoA NARI, UoA CA, Hamelmalo Agricultural College, CDE)	Development of innovative technologies, advice, training Backstopping, cooperation
Local Government	Political and organisational support
NGOs and international organisations	Funding and technical support
Farmers, represented by their various committees, especially Development Committee	Participation in planning, implementation, maintenance, awareness-raising, monitoring and evaluation

Note: The above list is the result of a brainstorming and is thus not exhaustive. A proper stakeholder analysis would help to complete it.

Communication can be improved through the following processes:

- Creating coordinating committees (at national, regional and local levels) that include farmers. This will help to bridge the gap between farmers, extensionists and researchers.
- Regular stakeholder meetings for planning and progress control have to be institutionalised.
- Regular sharing of information must be facilitated and appropriate, stakeholder-specific information tools must be developed and introduced (i.e. pamphlets, discussions, demonstrations…).
- Field testing and field demonstrations are a practicable way to show progress and develop new ideas.
- Regular reports from the village development committee on:
  - progress, problems, solutions, new ideas related to SWC measures
  - day-to-day SWC activities and agricultural problems observed in the watershed
- Training should be provided for farmers and relevant committees.

Initial steps to establish a "stakeholder network" are:

- Awareness-raising through an initial workshop involving all stakeholders
- A representative watershed for demonstrations needs to be identified by all stakeholders
- Participatory assessment (socio-economic study, baseline survey)
- Establishment of a plan linked to a time-frame, including clarification of tasks and responsibilities

Working group 2

Theme 2: How can need- or demand-driven, participatory SWC research and implementation activities contribute to improved local livelihood conditions?

1. What is needed to increase social acceptance of introduced SWC measures?
2. How can SWC activities lead to a higher short-term economic benefit?
3. What is needed in terms of SWC to increase yields (productivity)?
4. How can the maintenance of existing structures be improved?

Results of working group 2

What is needed to increase social acceptance of introduced SWC measures?

- A definitive list of best practices must be based on a stakeholder analysis.
- Participatory development of SWC measures that fulfil farmers' needs and take account of the specific local conditions are needed.
- Stone and earth bunds are best accepted by farmers.
- Tied ridges occupy land and farmers are therefore not willing to accept them.
- Acceptance of SWC measures depends also on the land tenure system and the availability / scarcity of cropland.
- Tree planting requires area enclosures – preferably physical fencing, or "social fencing"
  - Lessons can be learnt from the successful enclosure at Quandoba village, which is approx. 100 years old.
  - Option: find other best practices in the area, maybe not only for area enclosures.
- Suitable tree species can be grown on bunds, and where necessary, regular pruning can minimise negative effects of trees.
- Trees were present for many years. We need trees to harvest fodder, fruit and wood, and we also need nitrogen fixing species – why not plant them on the bunds?
- Trees cast their shadow on the crops, thereby reducing yields; on small plots, trees interfere with ploughing.
- Individual long-term user rights would allow farmers to establish and manage their own tree-growing plot.
- Farmers call for government legislation to enforce and maintain tree planting. A 2005 proclamation mentions that tree ownership and management can be within the responsibility of communities, individual households, or the government.
- Farmers need to be convinced to plant multi-purpose trees by on-farm demonstrations.

- There is not enough grazing land; animals are forced to graze on cultivated fields.
- After implementation of SWC structures, regardless of the approach taken there is a lack of follow-up or any other mechanism that would enable an evaluation of the quality and the effectiveness of structures and the provision of guidelines with regard to necessary maintenance activities (by the MOA or the local administration or by the farmers).
- Farmers point out that they need incentives such as FFW/CFW in order to maintain current measures.
- Farmers need increased knowledge and awareness of the different types of measures and their potential benefits prior to implementation (training, demonstration sites).
- Farmers know that SWC is helpful, but they face constraints such as lack of manpower to apply it to the desired degree. Another limitation is that farmers cannot rely on farming alone, and thus cannot spend their time on maintaining SWC structures because they are busy with off-farm activities.
- Farmers cannot use their land all year round and therefore seek off-farm income during the dry season. Technologies that allow cultivation of fields all year round (e.g. irrigation, agroforestry) have to be promoted.

The following questions were addressed generally:

How can SWC activities lead to a higher short-term economic benefit?

What is needed in terms of SWC to increase yields (productivity)?

How can the maintenance of existing structures be improved?

- Off-farm trials (so called on-station trials) and demonstration of SWC measures should be conducted, and results should be presented to farmers before on-farm trials are carried out.
- Food-for-work or cash-for-work approaches are necessary; they are helpful tools to supplement farmers' income.
- Farmers mention that SWC measures require regular maintenance (every six months or once a year), but if the structures are on common land or the work is organised as a campaign, they consider incentives (FFW/CFW) appropriate.
- Rules and regulations (comments during plenary discussion):
  - Land use should be managed through traditional village laws and regulations.
  - Land re-distribution is still in place (*diessa*, i.e. redistribution of land every 7 years)
  - The 1994 land tenure system proclamation is not yet fully implemented.
- Every farmer should treat his own fields with appropriate SWC measures. It is suggested that village-based rules and regulations be introduced to avoid negative downstream effects of poorly maintained or broken measures. The discussion about the rules requires strong support from the MoA Sub-*zoba* Office.
- Trees and grasses:
  - Tree planting combined with a proper area enclosure is most likely to be accepted by farmers.
  - Impose monetary fines for those who cut trees illegally.
  - Trees were present for many years even in agricultural fields, and they had no negative effect on the crops and did not affect the yields.
  - Key areas for planting forage grasses are on the borders between farms fields, open ranges and forest areas.

Working group 2: Final summary of recommendations

1. Community needs to be mobilised
2. Community needs more knowledge on the different SWC measures
3. SWC measures need constant follow-up (monitoring and evaluation)
4. Bylaws are required to ensure that SWC measures are maintained
5. Communities should work together on individual farmers' fields so that they may all mutually benefit
6. SWC measures require continuous maintenance; this can be facilitated through CFW and FFW
7. Communities require external assistance, e.g. technical support, training, strengthening of local organisations (committees), etc.
8. It is a known fact that there is a water scarcity problem
9. On-farm demonstrations are required before disseminating new SWC technologies

Working group 3:

Theme 3: How can applied and participatory SWC research contribute to solving problems of increased land use pressure?

1. Competing demands for cropland and grazing land: Possible contributions?
2. How can the increased demand for fuelwood be addressed?
3. Are there options for increasing the vegetation cover?
4. How can the grazing management system become more sustainable?

Results of working group 3

Grazing land management:

- The current *tsig'e* land management system (fallow period that includes temporal closure, grazing and land preparation for next cropping cycle) addresses the needs for both cropland and grazing land; there is no need to change it.
- The *tsig'e* system should be encouraged and applied widely in the Afdeyu area in order to enhance sustainable land management. Integrated farming systems that make use of the synergies between livestock and crop production should be enhanced.
- One advantage of livestock grazing on cultivated land is that the animals defecate on the land when grazing, thus adding useful fertiliser (unless the animal droppings are collected for heating / cooking).
- Some farmers disagree with the *tsig'e* system, because grazing land is only available for a short period.
- Whether the number of livestock is too high or not is a controversial issue.
- Some farmers suggest decreasing the livestock population, as the grazing area is not sufficient to feed all animals. Consequently, however, the number of children would need to be reduced, since livestock is an important base of economic security (livestock is sold to buy food in times of food shortage).
- The available cropping area per household is small and there is not enough grazing land for the animals. It is not possible to allot additional land specifically for grazing due to land scarcity and a high population pressure (and the resulting need for cropland).
- Changing the system from open grazing (on cropland) to controlled grazing is not feasible, but there is a high need to repair / maintain the SWC measures damaged by the animals.
- In the villages, there are clashes between owners of oxen and owners of cows and sheep over grazing opportunities: priority is always given to oxen, since they are used as working animals for many steps from land preparation over planting up to threshing and have a high social and economic value; however, cows and sheep provide other benefits such as milk, meat, money income, and manure.
- In the past, there were sufficient grazing opportunities, but due to the increasing human population, we have had to parcel our land over into increasingly smaller plots. (Adi Jin is in a relatively better situation, because the population is small compared to their village land area.)

Fuelwood and alternative energy sources

- Electricity became available in Afdeyu in 2004, but the costs are expensive and electricity is not affordable for all. Other villages are not (or not yet) connected to the national power grid.
- The new “fuel efficient” stove (*mogogo*) is good – with some project assistance, more farmers could take it up (e.g. through micro-credits)
- Home solar systems could be useful (for cheap electricity, for cooking, light and other household uses). Nowadays, kerosene stoves are used – but the cost of kerosene should be lowered.
- It is possible to plant trees for fuelwood (or multi-purpose trees) in areas that are not convenient for cultivation such as on hillsides, along riverbeds, and on valley floors.

- Farmers propose to select one village zone as an experimental area for tree planting, application of SWC, and controlled livestock management. Successful experiments can then be repeated in the other village zones.
- We cannot plant trees or grasses as long as there is open, uncontrolled grazing.

Village rules for land management

Note: this topic was very controversial.

- The traditional law encourages farmers to use the land in an appropriate way, and if farmers manage their land well, the community can allow them to use it another two or three times. This system helps to develop a sense of ownership.
- There are traditional village rules for taking care of the land until it is redistributed, and if not appropriately treated, the land is taken away from the farmer.
- These rules are not enforced by the community or the government. In the discussion, it was said that if farmers maintained the land poorly, it was taken away from them and given to the community. This is impractical and emotional, there is no law to force farmers.
- The community is not making use of these rules, but if any farmer refuses to maintain and use the land properly, it should be taken from him and should be given to another farmer as foreseen in the traditional law.

Working group 3: Final summary of recommendations

Competing demands for cropland and grazing land: Possible contributions?

- Continuous maintenance of SWC measures that are influenced by the open grazing system.
- Control of the livestock pressure (make study on the carrying capacity of the land).
- Traditionally farmers cultivated the land for three years and left it fallow for the fourth year. They did this to combat land degradation. Fallowing helps the land renew itself and leads to a good harvest. During the fallow year, the land can be used for grazing.
- Allocate additional areas for grazing.
- Improve land management to improve productivity per unit area.
- Use cut-and-carry (stall feeding); very controversial.

How can the increased demand for fuelwood be addressed?

- By saving energy (improved stoves) and using alternative energy, i.e. solar power, wind power, electricity, and kerosene.
- Planting trees on hillsides, along riverbeds and on valley floors

Are there options for increasing the vegetation cover?

- Afforestation programme
- Area closure can be improved
- Introduction of multi-purpose grasses and tree species on croplands.

How can the grazing management system become more sustainable?

- Improvement of forage grass
- Use of improved crops with high biomass

Conclusions

All participants of the "first international Afdeyu workshop" were highly motivated to contribute to the discussion. The outcome of the workshop is a collection of statements made by the different stakeholders, which provide many insights into the most urgent problems of the area. In some cases, there are suggestions for solutions. However, the discussion of controversial and complex issues and the fact that many statements are not based on a common agreement between all participants, show that it is important to gain in-depth knowledge about these issues and to discuss them further.

The present output is a valuable contribution to the ongoing dialogue about future research and implementation in, and hopefully also beyond, Afdeyu, and it will help to focus on the approaches with the highest common acceptance. It is proposed to use this document as a basis for deciding on the next steps to be taken.

Most urgent problems identified

The **land tenure system** is one of the most frequently mentioned problems. It is a sensitive issue, and has been the subject of a lot of scientific and non-scientific work in the past years. It might be rewarding to study the available documents. Since land tenure issues are related to policy issues, it is not within the responsibility of a team concerned with soil and water conservation to take action, but the establishment of a platform for knowledge exchange and open discussions with stakeholders in Afdeyu might contribute to future policy planning.

Land scarcity is another prominent problem: a lack of grazing land, food shortage, decreasing income, a need for intensification, controversy on where to plant trees, etc. These problems are difficult to solve, but they provide a good starting point for planning future activities in Afdeyu. From the authors' point of view, the mitigation of land scarcity and its economic, ecological and social effects on local level should be a major objective for future planning and implementation activities in Afdeyu. Irrigation for cash crops, promotion of multi-purpose trees as well as the introduction of improved fodder species and crop varieties (e.g. high value crops) are potential development priorities.

Increasing **conflicts between local resource users** will most probably be one of the effects of land scarcity. It was often mentioned that there are already many conflicts over the use of the available land resources for crop growing or for grazing. Introduction of tools for participatory conflict management and conflict solving in the medium term could help to provide the local population with the necessary means to take over the responsibility for the management of their local resources.

The feasibility, advantages and disadvantages of alternative **energy sources** (i.e. modern stoves, solar power, electricity, kerosene, fuelwood etc.) should be well studied prior to introduction of any of these energy saving systems. Not only the ecological situation, but also the economic and social environment must be assessed. The study should investigate, among others, the technological effectiveness, economic viability, social acceptance, and ecological sustainability of the various alternatives.

Promising approaches

A proper **stakeholder analysis** would be an appropriate entry point into participatory multi-level, multi-stakeholder approaches to SWC. Many questions and issues raised during the workshop (e.g. questions 1, 2, 3, and 4 of the first group[4]) can only be answered properly on the basis of knowledge collected during such an analysis. Moreover, the analysis should also clarify the contribution of each stakeholder to effective implementation of SWC research for development. A clear organisational structure of the current, and, if different, also the future network for SWC implementation – from national to village level – must be drafted.

[4] 1) Which organisations / institutions have to be included into the process of planning and implementation? 2) What are the tasks of the different stakeholder groups involved? 3) How can communication be improved and secured between the stakeholder groups? 4) What (initial) steps (methods, tools) need to be taken in order to establish a "network"?

Demand-driven SWC measures should contribute **to increase the agricultural yield** and help improve the livelihood conditions of rural people who depend on their land resources. Increasing yields combined with improved rural infrastructure will raise the economic benefit from implemented SWC measures. SWC measures that are conservation-effective and offer economic benefits to the land users will become socially accepted among the local population.

Active **participation of local people**, i.e. the involvement of land users in design, planning, and implementation of SWC measures, is very important for the acceptance of introduced technologies. The main factor leading to failure of SWC measures implemented in African countries, including Eritrea, was not the choice of technologies, but the side-effects of inappropriate approaches used to introduce and spread SWC technologies among the end users. Participatory SWC development (from research to implementation) involves all stakeholders from the very beginning. **Key stakeholders** to be involved are representatives of the Ministry of Land, Water and Environment (especially those responsible for policy on land); the National Agricultural Research Institute (NARI); the local and regional administration; the local and regional bureaus of the Ministry of Agriculture; the College of Agriculture; other (e.g. external) scientists; and the local farmers.

Soil and water conservation is a topic that cuts across different agricultural activities. SWC strategies should be part of an integrated development approach that includes not only technical recommendations, but also takes account of social conditions and the economic framework of the given household, community, or region. To support the local population means to think beyond erosion control (i.e. beyond the treatment of a field, a farm, a watershed, etc). **More holistic approaches** are needed in future in order to move from the "old" soil conservation approach to better land husbandry approaches and promote sustainable land management (SLM). Agricultural intensification (e.g. through improved water management), along with appropriate measures to maintain the sustainability of the local eco-system, can contribute to addressing the problem of food security in a short term. In the medium and long term, alternative sources of income generation must be found in order to meet the needs of an increasing number of people.

The study team recommends the use of the **existing research sites** (Afdeyu, but also Amadir) as pioneer areas for research and implementation. In a second step, promising approaches or successful implementations as identified in the research areas can be further tested on other sites. Site-specific knowledge (in the case of Afdeyu, a database of ecological parameters of over 25 years) is a valuable scientific tool for research development and implementation.

Photo 42: *Stakeholder discussion on how participatory SWC research can help solve problems of increased land use pressure.*

Outlook for integrated SWC development in Afdeyu and its vicinity

In view of the existing land use system, the environmental conditions, and the increasing pressure on resources, there is a need to find new options to secure livelihoods, be they in agriculture (e.g. high-value crops, high-input agriculture, niche products) or in non-agricultural sectors. Participatory approaches are needed for the identification of socially accepted, economically viable and ecologically sustainable options to promote local development. Based on the report results and the outcome of the final workshop, the following paragraphs present a summary of proposed future action with regard to land management and soil and water conservation.

Proposed next steps

For further development of participatory and need driven research and implementation activities, it is recommended to carry out a proper **stakeholder analysis** in the area. This should be done by researchers of the University of Asmara in collaboration with experts from NARI.

Based on the results of the stakeholder analysis, an **expert group** comprising representatives of all identified stakeholders should be formed. This group will be responsible for designing approaches and implementing trials at the field level. Additionally, the expert group has to inform all concerned stakeholders from the beginning about the aims, concepts, planned activities and expected outcomes, thus making the research / approach more transparent.

Simultaneously a **monitoring group** should be set up to monitor the ongoing activities. This team again should contain members of all identified stakeholder groups but different from the members of the experts group to ensure independent and unbiased monitoring findings. Monitoring activities will focus on the planned outcomes and achievements as formulated by the expert group.

Regular **communication** / meetings between the expert and the monitoring group help avoid mistakes and guarantee a participatory and flexible design of research. Results of any activities must be communicated among all stakeholders. It is proposed to have a bi-annual meeting where results are presented, further needs identified, improvements discussed and promising approaches demonstrated. It is important to develop stakeholder-specific means of communication (e.g. scientific reports for scientists, Tigrinya reports for field assistants and local advisers, drawings, pictures or oral presentations for the local population, etc). A knowledge database, including all kind of results, documents and proposals should be built up in an office in the Afdeyu research station. All stored information must be freely accessible.

Basic principles for a participatory approach to research and implementation

- Research, tests and implementation must be need-driven (meaning there is a sound interest in at least one of the concerned stakeholder groups – supported by other stakeholder groups).
- Participation in discussions, as well as design and implementation of experiments and tests must be open for all stakeholder groups.
- Project design / management and monitoring must be carried out independently by different entities.
- Promising practices must be communicated and documented properly; field demonstrations for a wider audience will help to share the knowledge with other farmers (spreading effect).
- Communication and documentation of results and findings must include difficulties and possible errors (learning from errors).
- All group work is based on mutual respect for each other's knowledge. Practical (local) knowledge has the same value as scientific approaches.

References

Key informants

Local key informants and workshop participants

Table 44: Local key informants and workshop participants (⊠ = participation)

No.	Name	Position	Village	IM	KI	CS	PRA1	PRA2	WP
1	Abay Asghedom	Chief land distribution	Afdeyu	⊠	⊠	⊠	⊠	⊠	⊠
2	Abraham Gebrezgabher		Afdeyu		⊠	⊠			⊠
3	Abraham Tesfagabr		n/a			⊠			
4	Abraham Tsegezeab		Quadeba			⊠			
5	Abrehet Isak		Adi Jin				⊠	⊠	
6	Alganesh Tesfazion		Adi Jin				⊠	⊠	⊠
7	Amanuel Araya		n/a			⊠			
8	Amanzghi Bahta		Adi Jin				⊠	⊠	⊠
9	Andebrhan Misgun		Adi Jin				⊠	⊠	⊠
10	Andom Weldegabr		Quandoba				⊠	⊠	⊠
11	Asbu Haile		Quandoba			⊠			
12	Bereket Gebrengus		Afdeyu				⊠		⊠
13	Bereket Haile	Development committee	Quandoba		⊠		⊠		⊠
14	Bereketeab Gebrengus	Administrator Afdeyu; Chair person Tsehaflam	Afdeyu	⊠				⊠	
15	Bereketeab Semere		Tsehaflam			⊠			⊠
16	Berhane Gebrezgabher		Afdeyu			⊠			
17	Berhane Okbazghi		Afdeyu			⊠			
18	Biniam Kidane		Afdeyu			⊠			
19	Bisrat Teweldemedhin		Quandoba		⊠	⊠	⊠	⊠	⊠
20	Bokrezion Bahta	Adminstrator Adi Jin, chair person Adi Jin and Quandoba	Adi Jin	⊠			⊠	⊠	⊠
21	Ermias Habtezion, Priest	Priest; field distributor	Afdeyu		⊠	⊠	⊠	⊠	⊠
22	Ferej Asrat		Afdeyu		⊠				⊠
23	Fisheye Hadgu		Adi Jin		⊠				
24	Foto Tesfazghi		Quandoba			⊠			
25	Gebrai Hadgu		Adi Jin		⊠				⊠
26	Gebrehiwot Gebreindrias		Adi Asfeda			⊠			
27	Gebremariam Haile		Afdeyu			⊠			
28	Gebrezgabhier Segid	Village elder	Quandoba		⊠				
29	Gebrezghi Gebremeskel Hibit		Afdeyu			⊠			
30	Gide Medin		Afdeyu			⊠			⊠
31	Gilai Te'are		Adi Jin			⊠			
32	Girmai Sahle	Afdeyu administrator	Afdeyu			⊠			
33	Girmai Sbahtleab	Rural veterinary; land ownership committee	Quandoba	⊠	⊠				⊠
34	Gu'oy Megos		Adi Jin				⊠		
35	Habte Zeregabr, Priest	Priest	Afdeyu			⊠			
36	Hadgu Gebremaraiam		Afdeyu			⊠			
37	Hayelom Asfaha		Afdeyu			⊠			
38	Hayelom Gilagabr		Adi Jin				⊠		⊠

Legend		
	IM	Participant Initiation Meeting at Serejeka Administration
	KI	Key informant (mapping, group interviews and transect walks)
	CS	Case study (individual interview)
	PRA1	Participant PRA exercise No. 1
	PRA2	Participant PRA exercise No. 2
	WP	Workshop participant (Final stakeholder workshop, Afdeyu)

Table 44 continued: Local key informants and workshop participants (y = participation)

No.	Name	Position	Village	IM	KI	CS	PRA1	PRA2	WP
39	Hayelom Gulbet		Adi jn					⊠	
40	Hzkiel Tecleab		Adi Jin			⊠			
41	Keleta Tela		Adi Jin			⊠			
42	Kibrom Negassi		Quandoba			⊠			⊠
43	Kiflemariam Gebremeskel	Serejeka Administration	n/a						⊠
44	Letezghi Gebrezgabhier		Afdeyu			⊠			
45	Luchia Eyassu	Development committee	Afdeyu	⊠					⊠
46	Matewos Gebrekristos		Quandoba		⊠		⊠	⊠	⊠
47	Meaza Eyob		Afdeyu			⊠			⊠
48	Mehari Embaye		Afdeyu			⊠			
49	Menghsteab Gebreselassie	Land ownership committee	Afdeyu		⊠		⊠	⊠	⊠
50	Mengis Mosazgi		Afdeyu			⊠			
51	Merhawit Tekeste		Adi Jin				⊠	⊠	⊠
52	Mibrak Isayas		Afdeyu			⊠			
53	Mogos Seghid		Afdeyu			⊠			
54	Mulu Bokrezion		Afdeyu			⊠			⊠
55	Rezene Weldetnsie		Quandoba		⊠				
56	Russom Haile		Tsehaflam			⊠			
57	Russom Sibahtu		Afdeyu			⊠			
58	Samuel Hadghembes		Quandoba			⊠			
59	Surafiel Tedros		Quandoba			⊠			
60	Tafla Gebrehiwet		Adi Jin		⊠				
61	Tafla Habtezion, Priest	Priest	Tsehaflam			⊠			⊠
62	Teare Ristu		Adi Jin		⊠				⊠
63	Tekeste Michael		Quandoba				⊠	⊠	
64	Tekie Sebhatu		n/a			⊠			
65	Teklay Asmalash	Chair person development committee	Quandoba	⊠	⊠				⊠
66	Tekle Tesfazion		Quandoba				⊠	⊠	⊠
67	Teklemariam Embaye	Local soil and water conversation specialist	Afdeyu		⊠	⊠	⊠	⊠	⊠
68	Teklesenbet Kahsay	Local judge	Afdeyu		⊠		⊠	⊠	⊠
69	Tesfahiwet		Afdeyu		⊠				
70	Tesfahiwet Meres'e	Serejeka Administration	n/a						⊠
71	Tesfahiwet Tela		Tsehaflam			⊠			⊠
72	Tesfai Gebreamlakh		Afdeyu			⊠			
73	Tesfay Kibrom		Tsehaflam			⊠			
74	Tesfayohannes Gebrezgabhie		n/a					⊠	
75	Teweldemedhin Weldeselassie		Adi Jin		⊠				⊠
76	Tewhbo Daniel		Quandoba		⊠				
77	Tsegay Teklemariam Zerazion	Priest	Afdeyu			⊠			
78	Weldeyesus Embaye	Afdeyu Research Station guard	Afdeyu		⊠	⊠		⊠	⊠
79	Werede Gebretnsie	land ownership committee	Quandoba	⊠					
80	Werede Kahsay		Afdeyu			⊠			
81	Yemane Misghun, Priest	Priest	Adi Jin		⊠				⊠
82	Yodit Efrem		Adi Jin				⊠	⊠	⊠
83	Yosief Gilemariam		Afdeyu			⊠			
84	Zeregabier Alazar		Afdeyu			⊠			
85	Zeremariam Gebreyesus, Priest	Priest	Afdeyu			⊠	⊠	⊠	⊠

IM Participant Initiation Meeting at Serejeka Administration
KI Key informant (mapping, group interviews and transect walks)
CS Case study (individual interview)
PRA1 Participant PRA exercise No. 1
PRA2 Participant PRA exercise No. 2
WP Workshop participant (Final stakeholder workshop, Afdeyu)

Expert key informants and workshop participants

Table 45: External experts and workshop participants (⊠=participation)

No.	Name	Institution / Position	WP	ST	Ex
1	Abraham Daniel	MoA *Zoba* Maekel	⊠		⊠
2	Andemichael Misghina	CONCERN	⊠		
3	Asmerom Kidane	Natural Resource Management, NARI, MoA	⊠		⊠
4	Aster Weldezghi	MoA Head Quarter	⊠		⊠
5	Batseba Tesfay	SLM Programme Eritrea	⊠		
6	Brigitta Stillhardt	CDE, University of Berne	⊠		⊠
7	Danyom Tumzghi	Toker Project	⊠		
8	Dawit Mebrahtu	NARI, Irrigation Unit	⊠		⊠
9	Estifanos Bein	MoA, Regulatory Department	⊠		⊠
10	Gebreamlak Araya	Ministry of Information	⊠		
11	Goitom Zewenghel	NARI	⊠	⊠	
12	Haile Gidey	MoA *Zoba* Maekel; Head	⊠		
13	Helen Habte	MoA Head Quarter	⊠		
14	Henok Eyassu	NARI	⊠	⊠	
15	Hiyabu Habtom	NARI	⊠		
16	Iyob Zeremariam	MoA			⊠
17	J. Oranje	DIA Eritrea	⊠		
18	Kiflemariam, Abraha	NARI			⊠
19	Kiros Gebrehiwet	WAT/SAN Techn.	⊠		
20	Letezghi Kibreab	Toker Project	⊠		
21	Mats Gurtner	CDE, University of Berne	⊠	⊠	
22	Mehreteab Tesfay, Dr.	College of Agriculture, UoA	⊠		
23	Merhawit Debessai	SLM Programme Eritrea	⊠		⊠
24	Neguse Abraha	NARI	⊠		
25	Omar Jabir	Watershed Mangement, NARI, MoA; College of Agriculture Hamelmalo; Division head	⊠		⊠
26	Paul Roden	SLM Programme Eritrea	⊠	⊠	⊠
27	R. Shyam, Prof	College of Agriculture, UoA	⊠		
28	R.P Tripathi, Prof	College of Agriculture, UoA	⊠		
29	Robert Burtscher	SLM Programme Eritrea			⊠
30	Russom Alem	MoA Serejeka	⊠		⊠
31	Ruth Belai	Translator	⊠		
32	Saba Ghirmai	NARI	⊠		
33	Saliem Beyene	Translator	⊠		
34	Samuel Mosazghi	MoA *Zoba* Maekel	⊠		
35	Semere Amlesom	NARI, MoA; Former Director General			⊠
36	Semere Asmelash	NARI, MoA, field technician Afdeyu research station	⊠		⊠
37	Semere Zaid	College of Agriculture, UoA, Soil and Water Conservation			⊠
38	Tedros Mesfin	College of Agriculture, UoA, Soil sampling and analysis			⊠
39	Teklemariam Berhane	Agricultural Engineering, NARI, MoA	⊠		⊠
40	Teklezghi Tekie	Hamelmalo College of Agriculture, Graduate Assistant	⊠		
41	Teklu Teweldebrhan	NARI; Soil scientist			⊠
42	Tesfaalem Zerai	NARI	⊠	⊠	
43	Tewodros Gebru	MoA DRS water resource unit	⊠		
44	Yonas Hadgu	Water Resource Department WRD	⊠	⊠	
45	Yosief Embaye	Livelihood P.M Oxfam	⊠		
46	Zeremariam Gebremichael	NARI IT	⊠		

WP Workshop participant (Final stakeholder workshop, Afdeyu)
ST Member of Study team
Ex External expert

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Appendices

Appendix 1: Methodology

Methods and steps of the field study

The present study is based on a combination of qualitative and quantitative data gathered during a field survey. Methodologically, data collection was based on two main approaches: (1) participatory field mapping, and (2) interviews with local and external key informants.

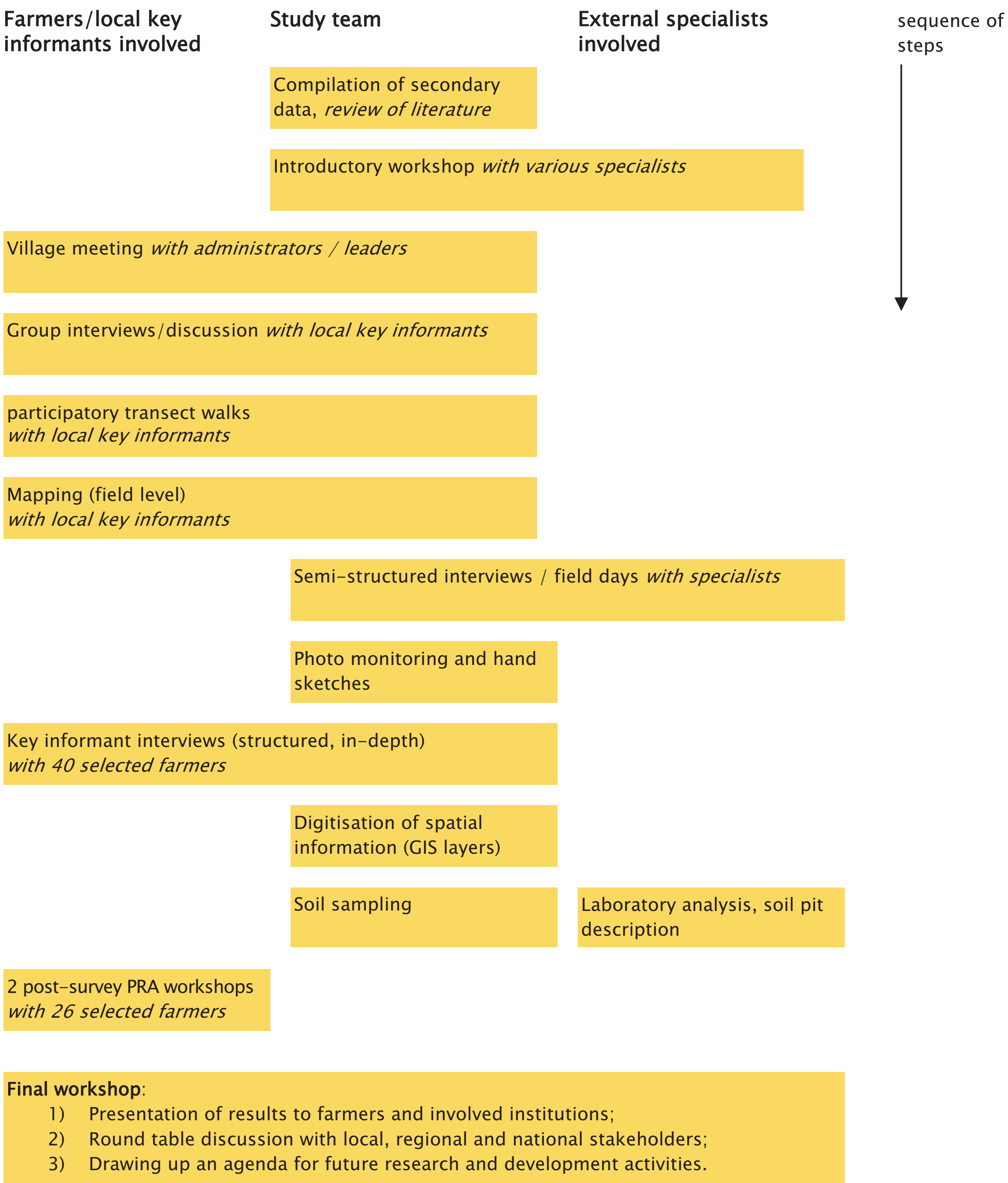

Figure 23: *Methods and steps of the field study*

Figure 23 places the different methods and steps in a chronological order and differentiates three levels of participating stakeholders: (1) the community, mainly represented by key informants, in collaboration with the study team; (2) the interdisciplinary study team; and (3) various external soil or SWC specialists supporting the study team.

Transdisciplinarity, i.e. the integration of local and external (scientific) know-how, and the dialogue between researchers and land users was a top priority of this study. Farmers' perceptions were emphasised and only in a second step complemented with specialists' opinions, observations and measurements. A range of different methods and tools were used, ranging from GPS-supported mapping to in-depth interviews (using standardised questionnaires) and several PRA methods. Data collection was largely based on participatory methods.

Mapping of SWC measures and soil types was based on an IKONOS satellite image with a resolution of 1 m (dating from 2000). In collaboration with the local key informants, mapping units were sketched on the image by hand, using systematic field observation complemented by GPS-supported mapping of points of special interest. Finally, the compiled information was digitised and integrated in a geographical information system (GIS).

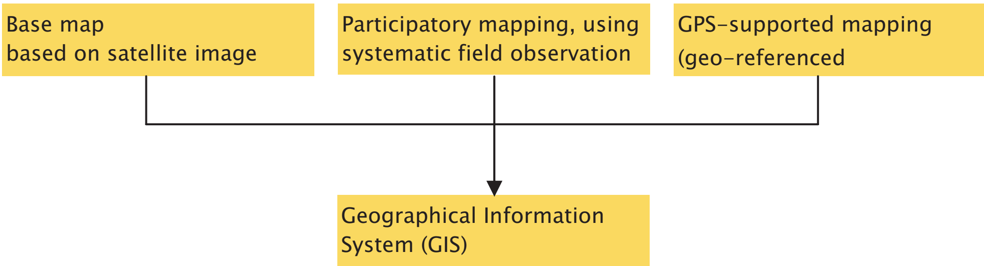

Figure 24: *Mapping procedure*

WOCAT

The **W**orld **O**verview of **C**onservation **A**pproaches and **T**echnologies (WOCAT) is a global network of soil and water conservation specialists which was initiated in 1992. WOCAT is organised as a consortium of national and international institutions of over 30 countries – including Swiss Agency for Development and Cooperation, FAO, UNEP, DANIDA, and Syngenta Foundation for Sustainable Agriculture. The WOCAT programme operates in a decentralised manner on initiatives at regional and national levels with backstopping from a management group.

WOCAT's **vision** is that existing knowledge of sustainable land management is shared and used globally to improve livelihoods and the environment.

WOCAT's **mission** is to support decision-making and innovation in sustainable land management by:

- connecting stakeholders
- enhancing capacity
- developing and applying standardised tools for the documentation, evaluation, monitoring and exchange of soil and water conservation knowledge

The **target group** comprises soil and water conservation (SWC) specialists, planners and decision-makers at the field and planning levels.

WOCAT has developed a framework for documentation, evaluation and exchange of knowledge on soil and water conservation. **Tools** provided by WOCAT include three comprehensive questionnaires and a database system which cover all relevant aspects of SWC technologies and approaches, including area coverage.

WOCAT's **database** currently comprises datasets on 135 technologies and 75 approaches, which are documented in a standardised way. The WOCAT knowledge base is in the public domain. Results and outputs are accessible in digital form, either via the internet (www.wocat.net) or on CD-ROM. A first Overview Book comprising a selection of 42 case studies from all over the world will be published shortly under the title "*Where the Land is Greener*".

For the present study, key questions of the WOCAT questionnaires on SWC technologies and SWC approaches have been selected. These questions have been adapted – where necessary – to the local circumstances and supplemented with specific issues according to the objectives of the study (e.g. focus on acceptance).

Questionnaires on SWC

The following questionnaire was used during the field survey for the individual interviews with farmers on specific SWC measures.

Introduction

1. Name of farmer
2. Socio-economic information about farmer
   - Household size: how many persons living in the house, how many children?
   - Type of house: *hidmo, modern house?;*
   - Do you sell some production surplus on the market? which crops? do you sell *a lot / medium / few*?
   - Is there off-farm income (by the family members / relatives)? *high (>1000 Nakfa /month) / medium (500-1000) / low (<500)*
   - Where and how do you spend your time when you are not working on your fields?
   - Which animals do you have? how many?
   - Special role / position / function in the village?

General questions

3. What are the main **problems** related to land use / agriculture? *1. Ask openly; 2. Give examples (see below); 3. Ask if these problems are low / medium / high*
   - is soil erosion a problem?
   - are the yields / is soil fertility a problem?
   - are there other problems?
4. What types of **SWC measures** do you have implemented on your fields? *1. Ask openly; 2. Give examples; 3. Exclude the measure on which this interview is focussing ("case study") as this is treated in details in the next section*
   - tied ridges: *may zehes zala; miseri tirsi*
   - grass strips: *nay sa'iri mekina'at*
   - tree planting: *migrab*
   - diversion ditch / bund (graded): *mieley wihig; mieley metreb / mkf'fal; mieley zala*
   - bent diversion bund / gully protection
5. **Why**? **Why not**? *Specify **reasons for adoption / implementation or rejection**! Specify **purpose** of measures!*
6. **When** did you carry out the last SWC activities in the field? What have you been doing? (e.g. maintenance of existing measures, implementing new measures, etc…)?

Specific questions on selected SWC measure (case study):

→ Give a detailed description of the SWC measure: design, technical specifications (measurements, etc.); steps of construction (implementation) and maintenance; purpose

7. Why do you use this SWC measure? → Find out about the reasons for adoption; Why do you think that other farmers don't use it?

*In case the farmer **does not** use this SWC measure:*

8. Why don't you use this SWC measure? → Find out about the reasons for non-adoption of a measure
   Why do you think that other farmers use it?

In case of lack of maintenance:

9. Why don't you maintain this SWC measure? → find out about the reasons for broken structures, reasons for lack of maintenance;

*In case the farmer **does** maintain the SWC measure:*

10. Why do you think that other farmers do not maintain this SWC measure?
11. What are the benefits, advantages, positive effects
    - biophysical: water erosion, soil moisture content, fertility, drainage, wind erosion, downstream siltation, other…
    - economic: increased production (comparison of yields before -after), reduced risk (e.g. loss of yields)
    - social:
12. What are the main **problems related to implementation and maintenance** of this SWC measure? *1. Ask openly; 2. Give examples and ask for importance → **See list below***

Seriousness / importance of problem →	zero	low	mod.	high	remarks
a) Loss of land					
b) Water logging					
c) Increased labour constraints (lack of time)					
d) High costs; lack of funds to purchase equipment/agric. inputs					
e) Low durability (easily destroyed)					
f) Land tenure system (diessa); land fragmentation					
g) Lack of knowledge (lack of training)					
h) Lack of organisation, collaboration (between farmers)					
i) Social conflicts					
j) or k) Lack of legislation (e.g. special laws to encourage SWC)					
other:					

13. Why are these problems occurring? When and where do they occur?
14. **Solutions**: how do you manage the problems? What are the possible solutions?
    What and how much are you willing to invest in solutions (human and financial capital)?
15. What are the constraints to invest in solutions?
16. **Campaigns**: do you think that campaign are a good solution? Why? Why not?
17. What is your main purpose to participate in a campaign?: Convinced by SWC?; Source of income?; Other reasons?

17b) Were the provided **incentives** satisfactory (did they cover your needs)?
  - if yes: could you implement this measure without incentives?
  - if no: what should be improved?

18. **Cost-benefit-ratio**: how are the benefits compared to the costs of this measure?
19. **Approach**: Is this measure introduced, indigenous, "farmers initiative" or modified (adapted)?
20. How did you **learn** about this measure? Did you receive training on implementation of measures? Was the training good? Was there technical assistance during and after implementation (by leading farmers / by field technicians?
21. How was it **implemented**?
    - spontaneously (adoption without receiving any incentives, farmer-to-farmer, etc.) *specify*
    - receiving incentives *specify type of incentives: food-for-work (FFW), cash-for-work (CFW), others*
    - pressure, sanctions *specify*
22. **Adaptations / modifications**: Have you adapted / modified / changed the measure regarding the original shape, layout, function, etc. (also in case of measures that are *replicated* by the farmer)
    if yes: 1. Please specify changes (layout, shape, additional techniques, etc...); 2. Ask about why they made the changes? What are the effects of the changes?
23. **Maintenance**: Does this measure require a lot of maintenance? Which maintenance activities? *(If not answered in the first question of this section)*; Frequency of maintenance? Is it a problem for you to maintain this measures? Why?

23b) Is maintenance integrated in existing land use system, land management activities?

24. **Where** is this measures applied *(e.g. only in shiebet, only in Gedena, only in hilly areas, etc.)*? Why?
    When was it implemented?

General concluding questions

25. Do you like the following SWC measures? Why? Why not?
26. Are they implemented in your fields? What is the main purpose? In case you don't have them: Why not? what is the main problem?

    stone terrace (traditional): *mdldal*
    stone bund: *kinatawi zala*
    earth bund: *metrabawi zala*
    combined stone and earth bund: *kinatawi metrabawi zala*
    tied ridges: *may zehes zala; miseri tirsi*
    grass strips: *nay sa'iri mekina'at*
    tree planting: *migrab*
    check dams: *ketari*
    diversion ditch / bund (graded): *mieley wihig; mieley metreb / mkf'fal; mieley zala*
    bent diversion bund ("rip of goat")/ gully protection

27. Are the existing SWC measures enough (in quantity / quality)? If not: How to improve the situation? If they say: We need better maintenance: → **How** can this be achieved?
28. Problem of insecure land use rights: re-distribution of land...

Appendix 2: Tables on SWC measures

Geo-referenced examples of SWC measures

Table 46: Coordinates of geo-referenced SWC measures

Point	Latitude	Longitude	SWC measure
1	1714009.69	484725.40	Traditional stone terrace
2	1714855.81	485206.30	Traditional stone terrace
3	1714699.90	485882.88	Traditional stone terrace
4	1714997.04	486200.95	Traditional stone terrace
5	1713668.68	484690.17	Traditional stone terrace, newly built (on farmers initiative)
6	1713295.83	484718.06	Traditional stone terrace very high
7	1713590.33	485225.34	Traditional stone terrace, 2 m high
8	1714539.49	486179.62	Earth bunds
9	1714843.34	486355.57	Earth bunds
10	1715072.84	486155.44	Earth bunds
11	1714486.86	486140.87	Earth bunds
12	1713991.23	484631.07	Mobile bunds
13	1713624.32	484662.09	Mobile bunds
14	1713767.93	485687.73	Mobile bunds
15	1713770.80	485549.42	Mobile bunds
16	1714589.06	485897.67	Bent diversion bund, to protect check dams in valley
17	1714654.08	485891.26	Bent diversion bund, to protect check dams in valley
18	1714080.92	485905.93	Stone diversion bund
19	1714695.62	485064.98	Roadside erosion control: stone bunds, small check dams, diversion structures along new road
20	1713660.48	484316.03	Bent diversion bund
21	1713521.24	484272.81	Bent diversion bund above gully
22	1713989.65	484684.23	Stone diversion bund
23	1714017.04	484592.02	Diversion bunds (to divert runoff to dry areas)
24	1713710.69	484624.26	Roadside runoff harvesting (small diversion bunds)
25	1713890.50	485133.29	Diversion bunds
26	1714007.91	485077.42	Diversion canal (bund)
27	1714131.94	484981.07	Diversion bunds
28	1713970.24	485731.94	Small dam
29	1713267.34	486099.01	Check dam to rehabilitate broken terrace riser
30	1713557.82	485693.43	Gully rehabilitation (checkdam and bent diversion bund) now levelled and cultivated
31	1713618.80	484425.83	Gully rehabilitation (checkdam and bent diversion bund)
32	1713559.50	484691.36	Gully rehabilitation (checkdam and diversion bund), levelled and cultivated
33	1715501.07	486189.11	life fences between settlement and cropland
34	1715534.13	486028.63	life fences between settlement and cropland
35	1713964.59	485689.28	Afdeyu enclosure
36	1716416.78	485344.72	Adi Jin enclosure; plantation of eucalyptus
37	1715725.32	485812.68	Adi Jin enclosure; plantation of eucalyptus (individually owned)
38	1713507.39	485354.61	Furrow irrigation
39	1714055.17	485662.57	Stone and earth bunds, replacing stone terrace (which was not built along the contour)
40	1713540.38	484079.69	Stone and earth bunds, newly constructed by farmer's initiative
41	1714945.29	486101.46	Stone and earth bunds
42	1713827.20	485646.85	Stone bunds, newly constructed by farmer's initiative
43	1713666.69	485490.27	Stone bunds, newly constructed by farmer's initiative
44	1714442.02	485892.72	Stone bunds, newly constructed by farmer's initiative
45	1714850.52	486464.93	Stone bunds, newly constructed by farmer's initiative
46	1714043.34	484610.07	Stone bunds, newly constructed by farmer's initiative

Table 46 continued: Coordinates of geo-referenced SWC measures

Point	Latitude	Longitude	SWC measure
47	1714695.62	485064.98	Stone bunds on both sides of the road, by farmer's initiative
48	1714076.58	484559.16	Stone bunds, newly constructed by farmer's initiative
49	1713278.34	484631.11	Stone bunds for runoff control (outlet under new road)
50	1714857.60	486378.85	Stone bunds, newly constructed by farmer's initiative
51	1713851.65	485353.13	Tied ridges
52	1713851.52	485325.84	Tied ridges
53	1715126.52	486326.83	Tied ridges
54	1713555.89	483963.91	Tied ridges
55	1713802.23	485656.42	Tied ridges
56	1713572.00	486256.20	Tied ridges
57	1713597.02	485606.88	Tied ridges
58	1713853.81	486254.71	Tied ridges
59	1713460.11	485950.29	Tied ridges
60	1713646.81	485878.16	Experimental *fanya juu* / double ditch
61	1714065.09	484617.92	Check dam
62	1713595.18	483944.81	Check dam
63	1715395.87	484060.38	Check dam
64	1714190.76	485051.26	Series of 8 huge check dams, with outlets
65	1714385.43	486115.66	Series of check dams along the natural waterway near the old road (Afdeyu-Quandoba)
66	1713591.18	483960.78	Check dams, big
67	1713681.42	484333.07	Check dams (big stone, by farmers initiative)
68	1714062.60	484608.01	Series of 12 check dams, gully is rehabilitated
69	1713642.39	485954.93	Check dam, gully is rehabilitated and cultivated
70	1714160.66	485155.79	Check dams combined with stone bunds, gullied area is rehabilitated and cultivated
71	1715189.49	484561.04	Hillside terraces / stone and earth bunds / micro-basins / afforestation
72	1715136.47	485064.18	Afforestation area / hillside terracing
73	1714860.98	484806.18	Afforestation / hillside terracing: cut trees, now regrowing
74	1713323.36	484570.92	Afforestation / hillside terracing near Afdeyu village: individual ownership
75	1715204.30	483699.79	Microbasins: triangular shape / afforestation
76	1715233.17	483910.06	Microbasins: typical half moon / afforestation
77	1715150.38	484001.84	Microbasins / hillside terraces / afforestation
78	1715040.12	483984.03	Microbasins: typical half moon
79	1715392.77	484316.84	Agroforestry
80	1714191.94	485956.83	Grass strips (remains)

Comparative tables on structural SWC measures

Table 47: Comparative characterisation of different types of terraces and bunds

	Traditional stone terraces	Hillside terraces	Stone and earth bunds on cropland*	Permanent earth bunds
Approach	local	only introduced	introduced, later also replicated by farmers (spontaneous adoption)	local
Land use	cropland	uncultivated land / afforestation areas (land which is not suitable for crop production)	cropland	cropland
Topography	gentle to moderate slopes, rarely on steep slopes (near settlement, in valleys)	undulating, steeper slopes (> 30%)	gentle to moderate slopes (< 20%, max. 30%)	gentle to moderate slopes (< 20%, max. 30%)
Establish-ment	unclear, 2 options: 1) cut and fill 2) gradual development from bunds / field boundaries	terraces are shaped manually behind stone walls using the "cut and fill" method	periodically enhanced bunds develop into slow-growing terraces through continuous siltation (accumulation of eroded soil)	they develop over years on the small unploughed strips of land that separate two neighbouring fields (no active construction)
Layout	not exactly along contour, staggered, not continuous, high risers (up to 5m!); frequently bench terraces; moderate to wide spacing	along contour, narrow spacing; continuous, not very high (1 m), levelled (at least near the riser, where micro basins are located)	along contour, wide spacing; not very high (1 m), continuous, forward sloping	frequently they do not follow the contour line
Purpose	expansion of arable land on steep slopes, conservation of moisture and manure, prevention of soil erosion	water harvesting for tree plantation (often in combination with micro-basins), stabilisation of hillsides, prevention/reduction of soil erosion	prevention of loss of topsoil and manure on agricultural fields, runoff regulation, moisture conservation for improved crop growth; avoid downstream siltation of dams	originally, the main purpose of earth bunds was ***not*** soil and water conservation but demarcation of properties
Comments	often modified during externally initiated SWC campaigns	when not fully developed they are sometimes hardly distinguishable from stone bunds (similar shape)	stone bunds and terraces mostly mentioned as the same measure	Soil embankments are often covered with naturally growing grass

Table 48: Comparative characterisation of tied ridges and rectangular micro-basins

	Tied ridges	Micro-basins
Approach	introduced	introduced
Land use	cropland	afforestation
Topography	gentle to moderate slopes	moderate to steep slopes
Establish-ment	excavation of ditch and construction bund	rectangular micro-basin: excavation of basins and establishment of bund (option: half-moons, see)
Layout	rectangular basins along bund (ditch which is divided into 7-10 m long sections by small side ridges)	rectangular basins along bund; staggered half-moons between bunds
Purpose	soil conservation; in-situ water conservation (prevention of lateral flow)	water harvesting; for tree plantation
Comments	tied ridges and rectangular micro-basins look more or less the same	

Ranking of SWC measures

Table 49: *Ranking of SWC measures with regard to acceptance, area coverage, condition and efficiency.*

Structural measures	Acceptance	Area coverage	Condition	Efficiency	Avg. rank
Traditional stone terraces	4.55	4.72	2.60	4.90	4.19
Hillside terraces (for tree planting)	3.20	3.50	2.20	3.70	3.15
Stone and earth bunds on cropland	4.00	4.28	2.70	4.40	3.85
Stone bunds	3.80	3.83	2.40	3.80	3.46
Permanent earth bunds (boundary)	3.44	4.10	3.70	3.00	3.56
Earth bunds	2.00	1.20	1.40	1.60	1.55
Mobile bunds	3.44	2.50	2.10	2.80	2.71
Tied ridges	1.00	1.60	1.40	1.78	1.45
Micro-basins (for tree plantation)	1.66	1.30	1.60	2.35	1.73
Stone check dams	3.30	3.80	2.70	4.07	3.47
Gully / pipe reclamation	2.27	3.20	1.70	4.80	2.99
Water diversion and drainage	2.60	2.40	2.80	3.07	2.72
Vegetative	**Acceptance**	**Area coverage**	**Condition**	**Efficiency**	**Avg. rank**
Live fences (sisal)	1.50	2.10	1.80	2.40	1.95
Grass strips (on bunds)	1.66	1.80	1.30	2.28	1.76
Trees / shrubs on cropland	1.00	1.20		1.60	1.27
Afforestation / area closure	3.10	3.10	3.40	3.60	3.30
Permanent enclosure; natural veg. regeneration	4.28	2.60	3.20	4.14	3.56
Agronomic measures / fertility management	**Acceptance**	**Area coverage**	**Condition**	**Efficiency**	**Avg. rank**
Crop rotation	4.76	3.60		3.50	3.95
Fallowing (temporary enclosure)	4.88	4.80		4.70	4.79
Local ploughing system	4.70	4.00		3.50	4.07
Intercropping / mixed cropping	3.40	2.40		2.78	2.86
Compost / manure application	5.00	4.70		4.70	4.80
Fertiliser application	4.70	3.80		4.07	4.19
Stone mulching	1.50	1.40		1.85	1.58

Table 50: *Average rank of SWC measures*

SWC measures; sorted according to rank	Avg. rank
Compost / manure application	4.80
Fallowing (temporary enclosure)	4.79
Traditional stone terraces	4.19
Fertiliser application	4.19
Local ploughing system	4.07
Crop rotation	3.95
Stone and earth bunds on cropland	3.85
Permanent earth bunds (boundary)	3.56
Perm. area enclosure; natural veg. regeneration	3.56
Stone check dams	3.47
Stone bunds	3.46
Afforestation / area closure	3.30
Hillside terraces (for tree planting)	3.15
Gully / pipe reclamation	2.99
Intercropping / mixed cropping	2.86
Water diversion and drainage	2.72
Mobile bunds	2.71
Live barriers / live fences (sisal)	1.95
Grass strips (on bunds)	1.76
Micro-basins (for tree plantation)	1.73
Stone mulching	1.58
Earth bunds	1.55
Tied ridges	1.45
Trees / shrubs on cropland	1.27

Appendix 3: Glossary of Tigrinya terms and acronyms

Glossary of Tigrinya terms

Note: local names of plant species and place names (geographical denominations) are not included in the glossary. For a list of local plant species see Table 13, page 68.

Table 51: *Glossary of Tigrinya terms*

Tigrinya term	Translation in English	*Synonym (Tigrinya)*
zala abhrsha	generally bund in cropland	
aimi	2nd ploughing after fallow	
ashit	white stone (Quartz)	
akeza	spring rains (small rainy season);	*azmera*
ba'akel (ba'ekel)	soil type (not clearly defined)	
bodu	uncultivated (virgin) land/soil	
com	group of villagers	
diessa	community / village ownership	
dominale	state ownership: individuals pay tax to the government for the land they use	
deldal	general term for terrace / bund	*mdldal*
duka	soil type, brown, relatively deep and fertile soil with a high water retention capacity and a good soil structure; most common soil type in the area	
duk'e	manure, animal dung	
e'ka	sisal	
fahshaw	ashy (colour)	
fanya juu	[Swahili term] literally "throw it uphill"; contour bund with associated ditch at lower side	
fanya chini	[Swahili term] literally "throw it downhill"; contour bund with associated ditch at upper side	
gablawi zala	micro basin	*frki werhi*
gdme gdmi mhras	contour ploughing	*kinatawi mhras*
Gedena	village zone; land close to the village	
gelo	soils of fair quality, with limited water storage capacity and generally high gravel and stone content; develop on the Precambrian basement	
jirba	water tank for transport on donkeys	
hamed	soil	
hamukshtay	ashy, greyish	
hanfets	mixed cropping of wheat and barley	
hgag mmla'e	gully / pipe reclamation	*krar; gudguad mmla'e*
hidmo	traditional house (made of soil and wood)	
hiza'eti	area enclosure, area temporarily or permanently closed for grazing	
hutsa	literally sand; soil type of alluvial origin, develops typically along sediment-rich rivers	
kahmahse		
kadra	official term for fallow; farmers use it to refer to fields that are not under cultivation (= no ploughing or planting), but may be open for animal grazing	
kebesa	highlands 1500–2400 m asl (average temperature: 16–29°C)	
keih	red	
keih hamed	red soil, moderately fertile soil of a characteristic red colour; clayey to sandy texture, often occurs in combination with white gravel	
kebabi	*mmhdar kebabi* is an administrative level comprising 2–3 villages	
kelamitos	eucalyptus	
keih tsetser	soils with a high content of white gravel, mostly red soils	
kerim	second cropping season (after fallow)	
ketri (ketari)	check dam	
kinatawi zala	stone bund	*nay emni zala*
kinatawi metrebawi zala	hillside terrace; in the study area also used for soil / earth bund	

Table 51 continued

Tigrinya term	Translation in English	*Synonym (Tigrinya)*
konshim	artificial/chemical fertilizer	
kontera / meraguzo	lithosols	
kremti	summer rains (main rainy season)	
kremtawi ma'etot	students' summer campaign	
lesse	soil type: accumulation of eroded soil material to the lee of a river, very fertile, good nutrient availability, optimal water conditions,	
maekelay	moderate / medium	
maekelay hamed	soil of medium fertility with a moderate moisture storage capacity	
ma'etot	voluntary group work	
maffa	hidden outlet	
mahresha	local ox-plough	
medebawi zala	bench terrace	
medeku'e	compost pit	
me'eley wuhj	water / river diversion	
me'eley metreb	diversion ditch	*mkf'fal*; *me'eley zala*
megedi may	waterway	
meriet	earth, land	
m'esar terzi	tied ridges	*may zihz zala*
mesengele tiel	bent diversion bund (literally: rip of goat)	*kurbata*
metenfesi	outlet	
metrabawi zala	canal bund, along contour; soil bund	
mgrab	afforestation	
mgunbat	5th ploughing after fallow	
midquae	manuring	
mimgab	4th ploughing after fallow	
mirwah	ploughing to control weeds	
miwharar	intercropping	
mkyar zala	mobile bund, changing the site of the bund	*mg'az zala*
mlw'wat zeri'e	crop rotation	*mkyyar zeri'e*
mogogo	stove for making local type of bread (*injera*)	
Nakfa (Nkf)	Eritrean currency (at the time of research: 1 US$ = 13.5 Nkf)	
nay agrab mesmer	live fences	*hiwetawyan hatsur*
nay agrab mesmer ab hrsha	agroforestry; trees in cropland	
nay emni ketari	stone check dam	
nay emni shfan	stone mulching	
nay emni zala	stone bund; hillside terraces	
nay hamed zala	soil bund	*metrabawi zala*
nay sa'eri mekina'at	grass strips	
neghi	furrow	
nekli	second ploughing during 2nd (*kerim*) and 3rd year (*salsien*) of crop cycle	
kirar	gully	
regah	high gravel content, stone cover, field covered with small to medium-sized stones (diameter up to 20 cm) mostly of basaltic origin	
rekik	thin; → *rekik hamed*	
rekik hamed	shallow soil of low fertility with a poor water retention capacity, occurring mainly in steep areas; shallow soil	
risti	individual household / enda ownership	
reguid	thick, → *reguid hamed*	
reguid hamed	relatively deep and fertile soils with high water storage capacity; in the study area often used as a synonym for fertile → *duka* or → *shiebet*	*reguid hamed*
sa'eri	grass	
salsien	third cropping season (after fallow)	
shiebet	fertile, flat land; fertile soil, with a high water storage capacity	

Table 51 continued

Tigrinya term	Translation in English	*Synonym (Tigrinya)*
sibet	ploughing depth, which can reach up to 30 cm	
sito	1st ploughing after fallow	
teff	local food grain *(eragrostis tef)*	*taff*
teslas	3rd ploughing after fallow	
Tigrinya	local language (spoken in central Eritrea)	
tilmi	sub-plot on agricultural field, marked/sub-divided by furrows (ploughed) to facilitate sowing	
tsa'eda	white	
tsa'eda hamed	white soil, bright, beige to greyish-coloured soil with a very loose structure, low fertility and a low water retention capacity; highly erodible	
tsig'e	1) 1st year of cropping after fallow; 2) closure/fallow period	
tsimdi	local square measure; 1 hectare (ha) = approx. 4 tsimdi	
tsetser	high content of (white) gravel (small size, compared to → *regah*)	
tsebaria	soil type; occurs on volcanic parent material, generally sandy, on slopes. Classified as phaeozem according to the FAO classification	
tswar hamed	alluvial soil (*tswar* = carried)	*ekub hamed*
walaka	black soil, vertisol	*tselim hamed, lin*
warsay ykealo	national development campaign (includes infrastructure reconstruction / development, implementation of conservation measures, and other development activities)	
wefri lim'at	national service campaign: collective tree planting, establishment of check dams and hillside terraces by people in the national service	
weyna dega	agroclimatic zone (1500–2300 m)	
zer'e	sowing; seed	
Zoba; Sub-*Zoba*	Administrative areas; the country is divided into 6 *Zobas; Sub-Zoba* is a unit similar in extent to a District in other countries in the region	

Acronyms and abbreviations

***Table 52:** Acronyms and abbreviations*

asl	above see level
CA	College of Agriculture
CDE	Centre for Development and Environment (University of Berne, Switzerland)
CHZ	Central Highland Zone (of Eritrea)
etc	et cetera; and so on
FAO	United Nations Food and Agriculture Organization
GIS	Geographical Information System
GPS	Global Positioning System (satellite navigation system)
ha	hectare
MoA	Ministry of Agriculture, Eritrea
MoE	Ministry of Education, Eritrea
n.a.	not applicable
NARI	National Agricultural Research Institute, Eritrea
NGO	Non-Governmental Organisation
PRA	Participatory Rural Appraisal
Pt.	point
SLM	Sustainable land management
SWC	Soil and water conservation
TICD	TOKER Integrated Community Development
UoA	University of Asmara
WOCAT	World Overview of Conservation Approach and Technology

SLM Reports:

Report (1) A Baseline Survey for Sustainable Development of the Deki Lefay Community, Eritrea (1998)

Report (2) Tradition in Transition – Aspects of Rural Livelihoods in the Eritrean Highlands. A survey for sustainable development of the Adi Behnuna community, Eritrea (2001)

Report (3) Long-term Monitoring of Soil Erosion and Soil and Water Conservation in Afdeyu, Eritrea 1984 – 1998 (2002)

Report (4) Small-scale Micro Irrigation in Eritrea. A feasibility study of affordable micro irrigation technology in Eritrea (2003). Available as a CD-ROM

Report (5) Amadir. Livelihood and Resource Management in an Eritrean Highland Community. A development baseline (2005)

Report (6) Land Management in the Central Highlands of Eritrea. A participatory Appraisal of Conservation Measures and Soils in Afdeyu and its Vicinity (2006)

The corresponding Geographical Information System (GIS) for Afdeyu is available on CD-ROM

Other reports, published in partnership:

Soil and Water Conservation and Management in Eritrea. Current Status and Trends. Published jointly with AEAS/Association of Eritrean Scientists in Agricultural Sciences (1999)

Irrigation Development in Eritrea: Potentials and Constraints. Proceedings of the Workshop of the Association of Eritreans in Agricultural Sciences (AEAS) and the Sustainable Land Management Programme (SLM) Eritrea (2005)

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