Conceptualizing rill erosion as a tool for planning and evaluating soil conservation in Angereb watershed, Ethiopia: Methodological development

Research Report for Q505 project supported by Eastern and Southern Africa Partnership Program (ESAPP)

Gizaw Desta (2010)

Amhara Region Agricultural Research Institute (ARARI)

Table of contents

List of Tables

List of Figures

Abbreviations

ACED	Assessment of Current Erosion Indicators
REAM	Rill Erosion Assessment Method
ARARI	Amhara Region Agricultural Research Institute
CDE	Center for Development and Environment
CEP	Community Empowerment Program
EGS	Employment Generation Schemes
ESAPP	Eastern and Southern Africa Partnership Program
FFW	Food-For-Work
FINNIDA	Finnish International Development Agency
FPEESCP	Farmers' Participatory Erosion Evaluation and Soil Conservation Planning
ILDP	Integrated Livestock Development Project
ITCZ	Inter-Tropical Convergence Zone
LLPPA	Local Level Participatory Planning Approaches
MOARD	Ministry of Agriculture and Rural Development
NGO	Non-Governmental Organizations
PADETS	Participatory Demonstration, Extension and Training System
PLUPI	Participatory Land Use Planning and Implementation
PRA	Participatory Rural Appraisal
SIDA	Swedish International Development Agency
SLM	Sustainable Land Management
SWC	Soil and water Conservation
WFP	World Food Program

Acknowledgments

This technical report is based on the research project at Angereb watershed which was financed by Center for Development and Environment (CDE) through the East and Southern Africa Partnership Programme (ESAPP). I would like to express my deepest gratitude to the CDE/ESAPP for financially supporting the project. My special thanks are due to Prof. Dr. Hans Hurni for his comments in the preparation of the project and during my field work. I would like to express our deepest gratitude to the participant farmers in the study area who actively participated in the process, contributed innovative ideas, and for allowing us to carry out different measurements on their crop fields. Special thanks also go to the development agents, especially to Serkalem Abebe, and kebele administration in the study sites who played a facilitating role in motivating, organizing and follow up of the participatory process. I am also grateful to my institute, Amhara Region Agricultural Research Institute (ARARI) and Debre Birhan Agricultural Research Center for the provision of the facilities to conduct the field work and for the support in the administration of the project. I also enjoyed the support in many ways from Gondar Agricultural Research Center, Integrated Livestock Development Project (ILDP), and North Gondar Department of Agriculture and Rural Development while conducting the field work.

1. Introduction

Given the central importance of agriculture in the economic development strategy of the country, any deterioration in land resources poses serious consequences for Ethiopia's future sustainable economic development. Small-scale agriculture is the dominant sector in the economy of Ethiopia. However, it has become clear in Ethiopia that land use has gone contrary to the cause for its conservation. Land degradation has become a widespread phenomenon particularly in mountainous agricultural lands. A major environmental hazard associated with agricultural production in these ecosystems is soil erosion. Rapid population growth and economic needs push farmers to cultivate steeper and more fragile lands, resulting in an annual loss of 1 billion tons of top soil lost per year (Tefetro 1999). As a consequence, farm productivity is reduced to 1 to 3 % (Mitiku, et al, 2006). A certain level of environmental degradation is inevitable however; the critical issue is to ensure that the level of resource use remains consistent with society's development objectives. There are many reasons why soil degradation still occurs. Accelerated soil erosion induced by unlimited human activities is one of the reasons for widespread land degradation. Combating land degradation and investing in the soil conservation for future generations will be a major development task promoting sustainable land management. What is required is a holistic approach for planning, development and management of the land which methodically identifies human and environmental needs.

1.1 Problems of Soil Erosion

Soil erosion is a serious threat for environmental degradation in the mountainous landscape of the highlands of Ethiopia in both its economic costs and the areas affected. The hill slopes are under cultivation without using control measures and appropriate land management practices that result in low productivity, physical and ecological degradation. This part of the land increasingly experiences high pressure for agricultural production. Soil conservation and management practices do not correspond to the activities imposed on these land units. Poor land and water management practices and lack of effective planning and implementation approaches for conservation are responsible for accelerating degradation on agricultural lands and siltation of lakes, dams and reservoirs downstream. Mismanagement of the land is blamed on the land users themselves by assuming lack of their environmental awareness, ignorance or lack of responsibility due to the fact that they cultivate the land for immediate livelihood goals. Thus, from the beginning one has searched for external solutions and technologies that could help to stop erosion in Ethiopia (Yohannes and Herweg, 2000). Accordingly, the SWC approaches were established in account of the above assumptions.

1.2 SWC Efforts and Limitations

The transfer and adoption of the promoted SWC technologies remained low (Hurni, 1984; Million, 1996; Herwege and Lude, 1999; Bewket and Sterk, 2002; Mitiku, et al, 2006). According to Mitiku (2006) the list of reasons for low transfer and adoption by farmers are: the top-down approach in extension activities, standard soil and water conservation technologies, lack of awareness of land degradation by the land users, and land security issues. Yohannes and Herweg (2000) described the limitations of the existing extension approaches and clearly indicated the need for an improved SWC approach. The experience with the food-for-work approach and introduced SWC technologies shows that the existing extension system has largely over-simplified the complexity of natural and human settings and the interrelation of the biophysical and socio-economic issues. The authors concluded that ignoring land users knowledge to cope with their own problems was one of the reasons for this failure. Similarly Hurni (1986) indicated that introduced measures did not draw adequately on the accumulated and specific knowledge of which farmers have. Great attention was not given to the area specific soil erosion process based conservation measures before introducing large scale SWC programme to Ethiopia. Systematic approaches through local problem identification were missing and this has resulted in much lower impacts than expected. Ineffectiveness of SWC structures perceived by farmers was an important factor discouraging farmers from participating in SWC activities (Bewket, 2003).

Most of the SWC activities were designed using top-down approach. Since the implementation was through the food-for-work and currently through safety net programs, the approach has contributed to the dependency of farmers on government institutions and particularly on SWC extension program for the planning and implementation of conservation measures on their own lands. The previous conservation activities often failed to address such questions as:

- What do the local farmers consider? Lacks to participate farmers and include their preferences
- What are the local erosion indicators and appropriate SWC practices from farmers' perspective? Important farmers' erosion indicators and suitable practices with respect to farmers' knowledge and skill were missed to account in the planning and implementation process.
- To what extent the local erosion indicators and related causes taken into account to evaluate erosion and plan for SWC? This implies the method of technology development and verification was not based on local erosion and runoff assessments and suitable techniques to control it.

These questions had to be answered to help to design appropriate and sustainable erosion controlling strategies and approaches.

1.3 Research Problems and Questions

Low performance and adoption of SWC measures is the problem targeted to solve in the study. This problem is emerged mainly due to the lack of consideration to area specific erosion process based conservation technologies and knowledge and experience of farmers in the SWC extension system. Systematic integration of both the socio-economic factors (knowledge, attitude and preference of farmers) and technological requirements and characteristics is therefore needed.

The research questions:

1. What is the efficiency of existing SWC measures to control rill formation?
2. What SWC improvements are needed?
3. What are farmers' indicators to assess erosion risk and plan for SWC?
4. Do farmers perceive rill erosion as simple indicator of erosion and best represent farmers' perspective?
5. Do rills used to evaluate erosion prone areas and indicate where to plan control measures?

1.4 Importance of the Research

SWC technologies that fit well to the local biophysical and social conditions and acceptable by farmers are highly demanded. An appraisal of different soil conservation technologies must therefore take into account not only the technological means involved but also the approaches that are supposed to grant successful implementation of measures, the socio-economic environment, markets, infrastructure, extension and other services, and the socio-cultural structures (Mitiku, et al, 2006). To achieve this at small-holder farm level, there is a need for an understanding of specific land resources degradation factors and indicators, and farmers' decision-making capacity, and how is the farmers' reaction to respective indicators in planning management options. Linking the farmers perspectives and field erosion indicators can facilitate a farmer-participatory erosion research, evaluation, and conservation planning and implementation, aiding to replace top–down approaches by bottom–up and increase genuine participation to enhance adaptation of conservation technologies for sustainable land management (SLM). It is most likely to improve the transfer and efficiency of SWC measures. In this way compromisation of field level ecological and economic objectives of individual farmers can also be achieved.

Planning and implementation of SWC measures ought to be undertaken through farmer-participatory processes to ensure its sustainable adoption on the farm. Most soil and water conservation planning approaches relied on empirical assessment methods by experts and hardly consider farmers' knowledge of soil erosion processes. Farmers' knowledge of on-site erosion indicators can be useful in assessing the site-specific erosion risk before planning any conservation measures. Consequently, wide scale adoption of farmers' erosion indicators in evaluating the soil erosion risk and existing control measures may be a rational approach by which land-users undertake self evaluation of erosion status on their own farms. Taking such an approach reinforces the realism of how farmers perceive their interests, how they understand the way erosion impacts on their lives, and how they value the costs and benefits of any measures of conservation that may be promoted. Such an approach is also expected to facilitate the acceptance, transfer and application of technical findings and recommendations. By this way, they would probably get convinced to adapt and/or implement conservation technologies without external enforcement. According to Mitiku et al (2006) one element of SLM, establishing processes for improved and more straightforward adaptation of technological knowledge and increasing the testing of technologies, can be met by increasing farmers knowledge on practical field erosion and sustainable land management. The process needs to address different issues such as unsustainable production systems, SLM options, economical and environmental impacts of land degradation, etc.

The development of this project was inspired by the fact that farmers have continued to cultivate marginal and steep slopes for their subsistence living without the application of sustainable land management practices. The study therefore focused to solve the problems of SWC technology transfer and adoption by farmers in order to reduce the challenge of small holder farmers and the pressure on this part of the land use system. This can be achieved by sharing and upgrading the practical oriented knowledge of the land users on erosion processes and causes, and sustainable land management interventions. Different strategies were employed that support to build farmers self confidence and enhance their knowledge and awareness. Frequent group and individual field visits and subsequent discussions to reach a consensus in order to identify and determine erosion indicators and causes as well as to evaluate applied measures; farm erosion survey; estimation of soil loss retained on conservation structures; and group meeting and discussions on issues of erosion phenomenon and land management practices are the strategies followed. Special attention was paid to facilitating the land users to identify and analyze their farm erosion problems, causes and corrective measures by themselves. Using the new approach the land users enable to gain practical knowledge relevant for decision making to adopt and innovate SWC technologies. They able to identify critical erosion indicators, related causes and impacts; determine the critical erosion risk areas; evaluate the potentials and limitations of existing soil conservation technologies; plan and implement locally suitable soil and water conservation measures.

1.5 Research Objectives

Eventually, the project aimed to develop applicable erosion assessment and then conservation planning approach using farmers' erosion indicators that can serve as a tool to evaluate erosion risk and the efficiency of applied erosion control measures; and to plan soil and water conservation.

Specific objectives

1. To identify critical rill erosion areas and assess their causes
2. To design appropriate measures to reduce severity of rill erosion and test possible solutions together with farmers on their fields
3. To develop guideline for SWC improvements using local erosion indicator assessment methods based on field case studies
4. To prepare and publish a booklet (in Amharic and English) for extension agents jointly with staff of CDE

2. Application of Rill Erosion Processes for SWC Planning

Failures in SWC suggest that more detailed information should be used for appropriate layout and design of SWC measures – particularly where run on and erosion occur – what type of SWC is needed, and exactly where. It is also suggested that the performance of SWC should be better monitored over time. Rills and gullies indicate critical locations of a slope section, because runoff concentration is high. Knowing the critical locations of a slope means being able to minimize the risk of irreversible damage, to avoid failure with SWC, and thus to make it more efficient (Herweg and Stillhardt, 1999). For a specific area, it is therefore necessary to consider where, and how to start soil and water conservation. As a principle of erosion control, physical soil conservation measures should be built on critical locations where rills start to occur.

During severe rainfall, overland flow concentrates and after crossing a threshold value causes rill development resulting in high erosion rates (Rejman and Brodowski, 2005). This is the stage of rill erosion, leading gradually to gully erosion. Rill erosion is geomorphologically significant because runoff reaches its maximum detachment and transportation power when channeled into rills (Torri et al., 1987). Rills are generally defined as flow channels that can be obliterated by tillage. Rills are used to describe small forms of linear erosion, which result from hydraulic erosion by overland flow. Rills are visible and noticeable linear erosion features easily identifiable by farmers (Herwege, 1996). These processes of erosion would enable to assess spatial erosion development and identify the critical locations of erosion along the slope profile. In order to identify erosion prone areas to plan a control measure rills are simple and good indicators. The study made by Bewket and Sterk (2003) indicates that the rill survey approach gives good semi-quantitative information on soil erosion in real life situations of diverse farming and land use practices in a quick and inexpensive way. Thus, it is commendable for practical conservation-oriented soil erosion assessment purposes.

Traditionally, soil erosion processes by water have been estimated using runoff plot measurements and a wide range of erosion models. Because of lack of appropriate approaches to assess and evaluate soil erosion and soil degradation, the land-use planners in most countries have adopted recommendations that are based on modeling approaches that are not fitted to the local conditions. Consequently, current estimates of soil erosion have been subjective and have not enabled extension agents (or policy planners) to correctly estimate soil erosion and to accurately design cost-effective soil conservation plans in agricultural lands (Kilewe, 1986; Napier, 1989). Developing effective soil and water conservation thus require the use of locally applicable and simple method of assessment of topo-sequence changes and erosion processes at field scale. From conservation perspective, detail investigation and more consideration is required in the delineation and hydraulics of erosion source areas on more complex topographic surfaces. According to Herweg (1996), rill erosion is important for rapid assessment of erosion situations at farm level. It helps to get a quick overview of current soil erosion process in specific area where expensive plot-based and long-term erosion studies are not possible. Rill survey can help to distinguish easily the spatial units along a hill slope. Through rill survey, one can get some hints on what is behind rill erosion, which limitations may hamper successful soil and water conservation in the future (Herweg, 1996; Carucci, 2000; Rejman and Brodowski, 2005). Rill erosion assessment is therefore not only used to estimate the magnitude of spatial soil erosion damage but also used as a cost effective and simple assessment tool to plan and evaluate the layout and design of SWC. Visual observation of the spatial distribution and parameters related to geometry of rill formation are taken to represent the erosion processes for effective layout and design of SWC.

More over, the layout and design characteristics of SWC technologies are determined by other local environmental and socio-economic factors affecting erosion processes. As much as possible, most important factors of erosion should be taken into account for improving the design and layout of SWC. However, the assumed guideline for SWC implementation in Ethiopia have only suggested to use slope gradient and soil depth in order to decide the layout as well as design of SWC measures (Hurni, 1986). The guideline is based on the dominant limiting factors on two slope categories. For slopes greater than 15 % however, the layout of SWC is irrespective of the gradient factor which probably assumed a linear effect of slope on soil depth given other factors constant. This seems more general and needs further investigation. The available guidelines lack to include locally important erosion processes and hydraulic properties of the soil to know what magnitude of erosion and where it occurs critically.

3. SWC Extension Approaches

As a response to the drought episode of 1974, soil conservation programs were started to mobilize affected farmer to construct SWC structures in the country through food-for-work programs (FFW) funded by WFP. Latter on, WFP's relatively small-scale and fragmented FFW projects were consolidated under one support called "rehabilitation of forest, grazing and agricultural lands" projects in 1980. Since then, watershed or catchments approach became the government strategy for about one and a half decades. Following the regionalization policy, the planning, implementation and management of soil and water conservation program has changed from a centralized system to decentralized since 1992/93. Consequently, the planning and implementation of SWC program is evaluated, and the watershed and sub watershed level approaches were abandoned and a minimum-planning scheme, later developed into Local Level Participatory Planning Approach (LLPPA) was established.

Food for Work, Cash for Work, Local Level Participatory Approaches (LLPPA), Employment Generation Schemes (EGS) and the dominant regular approach called Participatory Demonstration, Extension and Training Systems (PADETS) are common SWC extension approaches based on catchment treatment under watershed and integrated agricultural development. In most cases what was perceived as participatory was in fact a top-down approach where the extension agent was forcing follower farmers to passively render their plots of land for experimentation rather than proactively engaging. Extension personnel were viewed as controllers and enforcers of government decrees rather than facilitators of transfer of technologies. In actual terms short-term benefits were emphasized rather than on long-term impacts since natural resources management is a long-term endeavor. Paradoxically the extension system imparted the "sense of dependency" syndrome on the farmers rather than stimulating them for better productivity (Fetien et al., 1996 in Mitiku, et al, 2006). In the top-down approach, soil conservation technologies were selected on the basis of technical criteria rather than according to the financial costs and benefits associated with their adoption. With such top-down planning, the target beneficiaries are largely passive recipients of externally conceived development proposals, all too often resulting in a lack of enthusiasm for project implementation by the intended beneficiaries, with poor establishment and maintenance of whatever physical structures, hedgerows, and woodlots were promoted. Participation, where it has occurred, has typically been a case of the professionals gathering data, analyzing it, preparing plans and then asking the local community if they agree, before requesting mobilization of local resources (notably labor) to implement these plans. Farmers have to date, limited opportunity to be actively involved in development and decision-making processes inherent in the management of their own areas and even less in policy formulation (Mitiku, et al, 2006).

According to Lakew et al (2000), several other methodological tools have been tried in the Amhara region at various places. A number of NGOs operating in the region used different participatory methodologies. For example, the Swedish International Development Agency (SIDA) encourages Community Empowerment Program (CEPs) and gives a lot of attention to traditional institutions and neglects externally established institutions. The Finnish International Development Agency (FINNIDA) endorses participatory rural appraisal (PRA), which is a good approach for quick problem identification, analysis and planning, but lacks implementation approaches; however, it is appropriate for participatory planning. Another approach is the participatory land use planning and implementation (PLUPI), which is currently used in Meket woreda (North Wello) by SOS-Sahel.

Land degradation can be understood from both social and environmental context, this context is so diverse from place to place and time to time that only a real local understanding or approach can provide insights into the fundamental issues. There is a general understanding that land degradation in the Ethiopian highlands is related to individual land use and management practices. Therefore, the key issue in reversing land degradation trend and in providing insights into potential solutions to land degradation problems is to understanding the factors that have driven the farmers to choose such practices. Drawing on these concepts, the participatory approach can be conceptualized as the interaction of individual farmer fields and communal landscape units (biophysical dimension) with the individual farmer or village community (human dimensions). The interaction determines the limits within which the conservation technologies are physically possible and viable and socially acceptable. However, often due to large scale planning units at watershed scale (sometimes unmanageable) the efforts remained unsatisfactory as a result of lack of genuine and effective community participation and limited sense of responsibility. The inadequacy observed in the participatory approach at watershed scale is related to scale and focus. At large scale of planning and implementation there are less focus to meet the requirements of smaller planning units which otherwise useful for integrated management of the natural resources.

4. Research Methodology

The characteristics of the SWC extension approaches and technology development methods are mentioned as reasons for the failure. These are:

- Top-down approach,
- Introduce sense of dependency syndrome,
- SWC technologies selected on basis of technical criteria,
- Farmers have limited opportunity to actively involve in development and decision making processes, and
- Focus on short term benefit rather on long term impacts and ecological aspects regarding SLM.

This study was therefore targeted to fill some of the limitations of the existing approach with an objective to develop applicable SWC extension approaches and methods for the improvement of SWC technology and enhance the transfer and adoption by farmers.

4.1 Study Area

4.1.1 Selection of the study area

The study area is located in upper Lake Tana basin at Angereb watershed. The study sub-watersheds have experienced visible symptoms of land degradation in the form of soil erosion at upper catchments and sedimentation of Angereb reservoir. Since the watershed is located in the interface between rural and urban areas the issue of integrated watershed management is difficult in the presence of different community interests and diverse rural and urban environmental factors. Based on recent study, the Angereb reservoir is reached at its half design life. Designing an integrated development plan using adaptable approaches for Angereb watershed as part of a sustainable solution to the ever-increasing burden of reservoir sedimentation, and minimize the pollution and contamination of the water supply to ensure the sustainability of the water supply is thus became an urgent need. The area is therefore most appropriate as a learning site for the improvement of sustainable land management practices to increase small scale productivity and utilization of reservoir water sources.

4.1.2 Location and description of the study area

Angereb watershed is located north of Lake Tana basin, near to Gonder town. Geographically it lies between 1394096 m and 1407336 m Northing, 328073m and 337991 m Easting. The altitude ranges from 2100 to 2870 m asl. The total area coverage is about 70 km^2. At the outlet of the watershed, Angereb reservoir is the main and only source of potable water for the Gonder town. The major landform of the watershed comprises chains of hills with mountainous ridge. This watershed can briefly be expressed by mountainous rugged south facing topography. The boundary of the catchment is characterized by rugged topography with chain of ridges bordering sub catchments within the area.. It is almost oval in shape with dendritic drainage pattern, steep ridges at the boundary, numerous convex hills inside the watershed and steep gorges. Angereb and its small tributaries have cut deep trenches that divide the catchment into several sub catchments. The slope classes in the watershed encompasses very steep (on the ridges) to gentle topography. The drainage patterns are dense in the topographic highs and relatively less dense in the topographic lows. In the northern and western part of the catchment, which is characterized by dense drainage pattern, there is a high runoff and erosion rate. This is due to the fact that this part is characterized by steeper slopes and intense rainfall distribution.

Areas with slope gradients less than 8 %, 8-30 % and greater than 30 % accounts for 11.5 %, 43.1 % and 45.4 % of the watershed area. At the intermediate and flat slope gradients the surface condition of the cultivated land is mainly covered with dense stone mulches (40.80 % according to Birru, 2007). Field observations showed that land parcels with significant stone cover have low erosion damage and relatively better crop production.

The land use of the watershed is covered by cultivated land (69 %), forest (10.6 %), grazing area (4.8 %), bush (7.2 %), Scrub (3.9 %), settlement (4.2 %) and wetland (0.3 %). The main crops grown in the area are dominated by wheat (37.9 %) followed by barley (27.9 %), teff (21.3 %), and horse bean (13.5 %). Agronomic practices used by the farmers are mainly traditional, which includes plowing with pair of oxen and hand weeding. There are some exceptions that use very small quantities of fertilizers and pesticide to limited areas of farmlands. However, the uses of these inputs are not reflected in crop yields, which are generally low. Mismanagement of land and its consequence on land resources substantially contributed to low production, currently below the national average. In most parts of the sub watersheds, the soils are shallow cambisol underlain by unconsolidated medium sized gravels with loose joints, which in turn underlain by watertight rocky layers. These layers are easily visible in some healing gullies and steeper part of the riverbeds. The dominant textures identified in this watershed are silty clay loam and silty clay. In this watershed all the soil depth classes are found but the dominant soil depths are between 25 and 100 cm.

The amount of rainfall in Ethiopia is influenced by the location of the place relative to the source of moisture, the direction of winds and topographical relief (Admasu Gebeyehu, 1996). The Atlantic Equatorial westerlies produce the big rain (May-September) in the area when the low pressure inter-tropical convergence zone (ITCZ) is located north of the country. The area gets very little or no rain from southerly and easterly Indian ocean air mass in spring (*Belg*) due to orographic and altitude effects. The watershed has characterized by variable rainfall distribution. The annual rainfall varies from 700 to 1800 mm with a mean annual value of 1160 mm. The mean annual rainfall varies from 710 to 1820 mm with a mean of 1160 mm. The intensity is generally characterized as low to moderate with few extreme values in July and August. Based on the long-term rainfall data (1952 - 2000) most of the rain occurs in July followed by August. The rainfall in May is also quite significant. The annual rainfall is generally decreased from year to year except in 1999, which has the second highest extreme value in the history of 45 years rainfall data. The watershed, on the other hand, has a very long dry season.

This study was specifically conducted at three case study catchments in the upper part of Angereb watershed. The catchments are located in Chira Kiltim Sebari, Chira Godguadit, and Arbaba Embis Tig villages consisting of 15 to 25 land holdings. The case study catchments are located in the two tributaries of the main Angereb river: Korebreb and Angereb at the top part of the watershed. The most important factors considered during the selection are: level of erosion problem, farmers' interest to participate, treatment by SWC, and accessibility for frequent follow up of activities. The catchments are characterized by steep topography greater than 30 % gradients and have apparent indicators of erosion problem. The catchments have streams suitable to monitor sediment concentration at the outlet. The cultivated plots are more or less treated with fragmented stone terraces and grass and shrub covered borders called *dib*. The land use is completely meant for crop production with pulse-cereal-fallow rotation system. Sparsely scattered trees (Olive, Acacia, Eucalyptus, and Croton species) are observed in some of the farm plots. The local shrub called *embacho* is also commonly grown along terraces and farm boundaries. This shrub supports and stabilizes the terraces and can be used to strengthen the terrace structures in the form of shrub strip.

4.2 Specific Methods and Procedures

The specific methods and procedures are discussed in depth in three components: 1) Farmers participatory erosion survey and SWC planning; 2) Survey of rill erosion; 3) Assessment of performance of existing erosion control measures.

4.2.1 Farmers' participatory erosion evaluation and soil conservation planning (FPEESCP)

The Farmers' Participatory Erosion Evaluation and Soil Conservation Planning (FPEESCP) approach is based on the use of farmers' knowledge base for erosion and SWC. The approach is designed to integrate the knowledge, skill, attitude and preference of farmers on the one hand and local erosion processes that limit the characteristics of the technology on the other hand. The methodological procedure constitutes to incorporate local demands and perceptions of soil erosion problems as an essential input to relevant research for development activities. The participatory process is developed in facilitating farmer consensus; for example, about which soil erosion indicators at individual fields are most important and what improvements to the existing conservation practices and potential erosion control options could be used. Building trust and local capacities for consensus building create a critical step prior to collective action by farming communities resulting in the adoption of integrated soil and water conservation strategies at the field and catchment/topo-sequence scale.

The procedures involve the following methodological strategies:

- **Self confidence building measures** – is related to awareness and attitude change activities to motivate farmers for their genuine participation and build trust. Self confidence building measures were done in the form of question and answer.

  The following non-structured questions and issues were points of discussion to stimulate farmers' confidence.

  - What would be the economical and environmental impacts of current land management practices, erosion and land degradation for future generation?
  - Given the continued erosion problem without appropriate management practices, for how long subsistence production continues under the current land management?
  - What is the historical decline in productivity?
  - How is the historical change in cropping/production and land use systems?
  - Explore most noticeable erosion and flooding events and historical land use changes and their consequences,

- Describe examples of successful community participation experiences and sustainable land management practices,
- Issues of migration as consequence of poverty, etc.

- **Group formation and participation of land users**

The participation was in such a way that all farmers were involved in the key collective decision processes. In addition, farmers' research team was organized to take active participation and decision through out the processes if it was difficult and unmanageable to involve all farmers. In both cases farmers were active leaders of the participation process. The extension agents, researchers and kebele administration played a role of facilitation and organization of farmers' interest.

- **Practical oriented knowledge sharing and upgrading**

Farmers involved to exploring their practical experience and knowledge about field erosion indicators, causes and impacts through periodical meetings, field visits and subsequent discussions; monitoring and measuring erosion processes; and evaluating control measures. All land users' should involve in the one-to-one and group visits, discussions, and implementation activities at their own and adjacent farm lands. Group formation was in such a way that those farmers who own land along the topo-sequence were categorized in same group in order to create enabling condition for discussion of their common problems and for analyzing the cause-impact relationships of upslope and down slope erosion sources.

- **Integrating assessment of field and landscape units**

In the small holder farming system the smallest and central decision making unit is the individual farm at household level. The starting point in the planning process was the individual farmer and other group of farmers owning land upslope and down slope of his parcel. Thus, focusing on the integration of field and landscape was a major tool in the erosion assessment and conservation planning process. Understanding land degradation processes began with an assessment at the individual farm and ends with the landscape or catchments following the flow of runoff water. Assessment has begun at field scale to evaluate the relative susceptibility of individual soil and crop management practices and to identify what sources of erosion. Assessments of erosion indicators, causes, impacts and performance of conservation measures was carried out by individual and group of farmers through periodical visits and discussions to reach consensus. The objectives of integrating field and landscape assessment were therefore:

- To gain an understanding of interrelation between cause-process-impact of erosion,
- To support a collective understanding of constraints,
- To facilitate land users or community linkages in the upslope and down slope,
- To create common responsibility due to manageable planning units (farm and landscape), and
- To develop a participatory development program.

The following procedures were carried out to explore farmers' knowledge and increase their awareness about practical oriented soil erosion assessment and conservation planning.

- Community awareness meetings,
- Field visits and discussions to explore erosion indicators, causes and impacts and their measurements,
- Identifying critical erosion areas and planning potential conservation measures and improvements;
- Implementing improved measures, and
- Monitoring and evaluating the performance of implemented measures through direct measurement of sediments trapped and rough nutrient loss estimation.

More specifically, individual and group field visits and discussions involved the following steps:

1. Farmers were called for a meeting and asked for their voluntariness and briefed on the objectives of the study.
2. Before the start of the field survey the participants were divided into appropriate number of groups based upon the adjacent land holding in the topo-sequence. The groups were formed in such a way that members of a group do not have their own land along the topo-sequence where the group assigned to visit. This gave an opportunity for participants to evaluate erosion problems at other farmers' plot and help for looking management options along the landscape.
3. Thereafter all the groups were assigned to visit and assess the respective landscape from bottom-up.
4. Identifying and recording sources (causes) of erosion: runoff source areas, crop tillage management, slope and slope length, poor conservation structures, land use, etc.
5. Assessing and identifying on-site soil erosion indicators and causes: sheet flow lines, rill channels, gullies, surface wash, sediment deposits, ditch erosion, tillage erosion, etc.

6. Identifying off-site erosion processes and causes: gullies, land sliding, sedimentation on field boundaries, etc.
7. Evaluating the magnitude of damage at on-site and off-site (adjacent farms) by individual farm owners and by group of farm owners along the topo-sequence.
8. Evaluating the impacts of on-site and off-site erosion processes: physical soil loss, soil depletion, yield reduction, low infiltration capacity, etc.
9. Corresponding to the sources and indicators of erosion; identify suitable and cost-effective technologies and practices, and assess points of improvements on existing conservation structures at both field and landscape levels.
10. Screen out the interventions and practices with respect to the prevention of conflicts among adjacent farm owners and from the aspect of integrated runoff water management and erosion control principles.
11. In the subsequent meetings all the groups came together and held discussions to reach consensus on the identified and listed erosion problems and suggested solutions for each individual lands. The discussions enabled the different groups to identify important erosion problems, erosion indicators, causes, and corrective measures in all the plots,
12. Next to the discussions made after the first survey, the groups were allowed to visit the individual plots for the second time to gain an in depth understanding of erosion processes and find improvements on the suggested interventions.
13. This procedure continued until the farmers reached an agreement on erosion problems and solutions for each individual field.
14. Minutes were recorded in a field book about the agreed erosion problems, solutions and implementation schedule according to priority of the problem,
15. Finally the implementation was conducted with possible flexibility in the layout and dimensions of the structures.
16. Monitor and evaluate the effectiveness of implemented erosion control measures/practices and identify further improvements with respect to controlling erosion and preventing conflicts among adjacent farm owners.

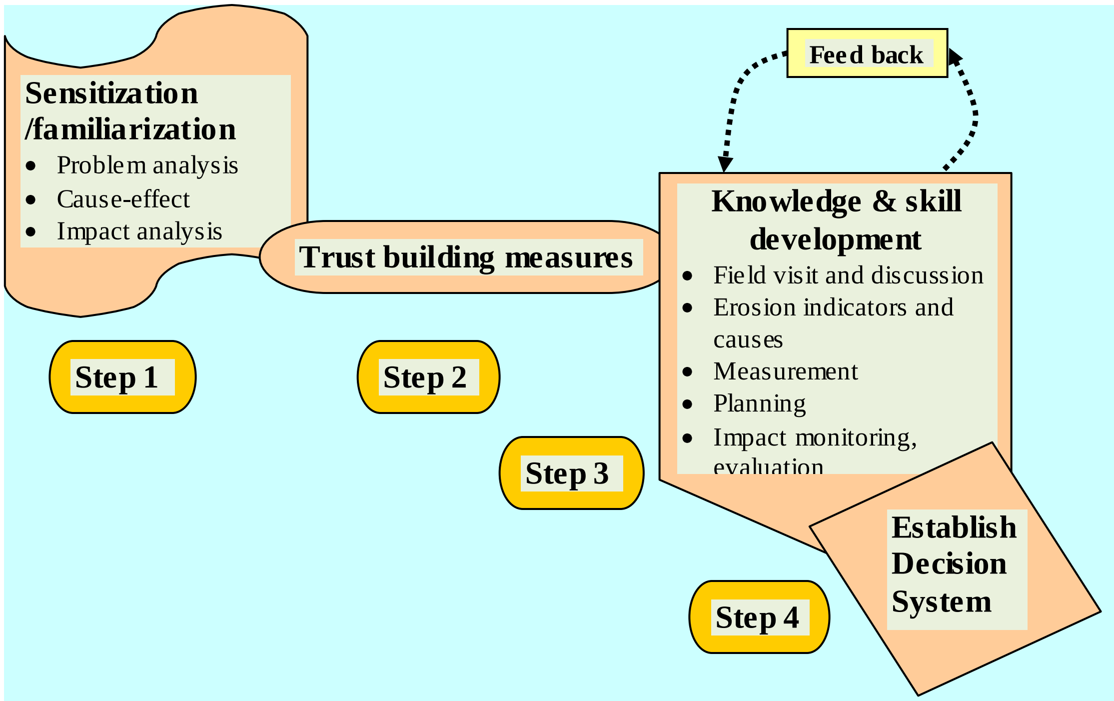

Fig.1 Steps for the participatory process

Moreover, throughout the field visits and subsequent discussions the following issues were targeted:

- ✓ *History and experiences of erosion events in the area,*
- ✓ *Land units and cropping practices susceptible to erosion,*
- ✓ *Estimation of existing soil depth and productivity trends,*
- ✓ *Farmers' erosion indicators, observed erosion problems and associated causes at each plot,*
- ✓ *How to measure a particular indicator?*
- ✓ *Critical erosion prone areas and associated indicators and causes,*
- ✓ *Construction and maintenance history of structures,*
- ✓ *Potentials and limitations of existing control measures,*
- ✓ *Do the existing erosion control measures protect rill formation?*
- ✓ *Improvements to be made to the existing SWC measures?*

The mentioned procedures were followed periodically for every heavy rainstorms and every season. Depending on the agreement reached by all land users and where the numbers of participant farmers were many to manage, periodical field visits to assess erosion as well as to plan control measures could be carried out by representative team of farmers (who have good experience and judgment). However, the assessment, planning and monitoring results were discussed by all land users to reach consensus for collective and acceptable actions.

The approach took a joint learning process that provides an opportunity for compromising technical solutions with farmers' consideration. It enhanced the farmers understanding of erosion processes and explored their knowledge. Most importantly it helped to minimize farmers' sense of dependency. This methodology had the most important advantage of flexibility and minimization of experts' interference. Aspects of erosion processes, erosion indicators, causes and (economic and environmental) impacts on land productivity and sustainable land management on the landscape and individual plots were explored through on field individual and group discussions.

Monitoring and evaluation of the constructed structures were made by all farmers and asked to estimate the amount of soil trapped by each structure (such as check dams, trenches, and terraces) to show them the impact of erosion as well as the controlling efficiency of the measures. All farmers together visited the newly constructed structures after heavy rainfall events. They estimated the amount of sediment retained by weight basis. At this step the facilitators have played great role to show the economic impact of soil loss. The sediment amount has to be converted into estimated nutrient loss and cost of fertilizer needed to compensate the soil nutrient lost by erosion. This procedure had brought the attention of farmers on erosion problem and they felt responsibility to conserve their land. For instance, the farmers were impressed by the high amount of soil trapped and filled up of the check dams during few storm events.

4.2.2 Survey of rill erosion

Among other indicators rill erosion (defined with depth > 5 cm) is one that farmers can easily perceive in their plots and a suitable indicator for seasonal monitoring of erosion and conservation measures. According to Herweg (1996), by visualizing the spatial distribution and development of rills on both terraced and un-terraced field one can easily understand the limitations of terraces as well as where to plan conservation measures. Visualizing the extent and spatial development of rill erosion on the topo-sequence is thus the concept taught and shared to farmers for erosion evaluation and SWC planning purpose. More over other erosion indicators such as gullies, sediment deposit, increase and/or decrease in terrace height, tree and stone mounds, exposed crop roots, decline in growth and yield of crops, change in soil depth and texture, etc., identified by the farmers were used to evaluate both the severity of erosion and its impact as well as the performance of applied conservation measures at farm as well as catchment scale.

Rill erosion assessment method (REAM) is directly adapted from ACED (Herweg, 1996) with particular interest for evaluation of rill erosion distribution and its magnitude for erosion assessment and for planning of SWC. REAM is meant not only for assessment of erosion magnitude but also for evaluating the efficiency and planning of SWC. All rills of depth > 5 cm and length > 4 m are perceived by farmers to create erosion damage. In the REAM method the distribution, magnitude and longitudinal development of those rills were characterized by the derived rill parameters calculated from the measured rill depth and width.

- Rill density and rill damage to show the distribution and extent of rill erosion
- Distance of rill formation away from the base of the upper terrace structure

Rill erosion survey: In addition to farmers own field assessment, survey of rill dimensions was conducted on systematically selected sample plots where rill erosion is commonly occurred. Rill survey was made immediately after the occurrence of significant rainfall events. A total of twenty three rill erosion sample plots were taken from three catchments (Chira Godguadit, Chira Kiltim Sebari, and Embis Tig). The rill survey was made by integrating samples of individual field plots into the landscape structure.

Topo-sequence survey: Rill survey at landscape units was made following the direction of runoff flow along the topo-sequence. The catchments were divided longitudinally into two transect sections (Fig. 2). Based on their relative position, sample plots within the transect section were grouped into upslope, middle slope and lower slope of the catchment in order to assess rill development along the topo-sequence. Each sample plots further classified and measurements were carried out between intra-terrace area (top, middle, and bottom positions in the open terrace area). Rill cross sections and counts were measured three times during July to August 2008. By surveying all rills; rill count, spacing, depth and width were collected from each sample plots and aggregated into intra-terrace and landscape positions to monitor rill development. In each slope section of the catchment rill count and rill cross-sections (depth and width) were measured directly using measuring tape from three random sample points of all rills occurred with depth greater than 2.0 cm. The mean was taken for a single rill. Rill characteristics collected at plot scale are used to evaluate efficiency of terraces and illustrated the development of rills over the slope profile. It also helps to assess the performance of terraces against rill formation and development.

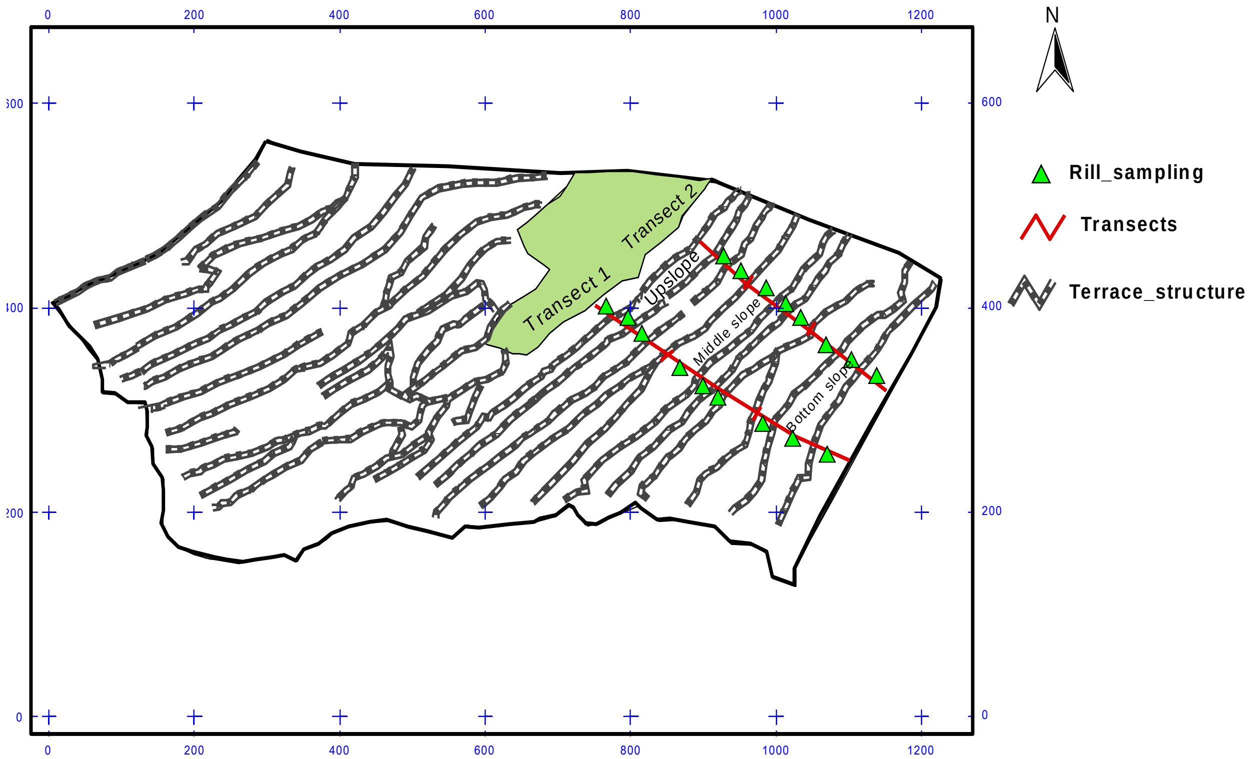

Fig. 2 Illustrations of rill survey sampling plots along transects at catchment scale

Analysis of rill erosion

Rill measurements were analyzed to obtain rill density and rate of rill erosion for each unit of observation (survey plots, intra-terrace areas, slope positions, and rill survey periods). Mean and standard deviation of the rill depth, width, rill density and rate of rill erosion were calculated. Rate of rill erosion is defined by rill volume per unit area,

$$Rate\,of\,rill\,erosion = \left(\frac{L_r.W_r.D_r.n}{SL.W_c}\right) = \left(\frac{L_r}{SL}\right)\left(W_r.D_r\right)\left(\frac{n}{W_c}\right) \qquad (1)$$

Assuming a parallel rill network in a very short slope length interval, rill length (L_r) is approximately equal to sampling slope length (SL). Rill density (R_d) is defined by number of rills (n) per unit contour width (W_c). Rill width (W_r) multiplied by rill depth (D_r) is the cross sectional area (A_x) of rills. Therefore equation (1) is simplified and rearranged into equation (2).

$$Rate of rill erosion = A_x . R_d \quad (2)$$

4.2.3 Assessment of performance of SWC measures

In complementary to the assessment and evaluation of erosion problems at field and catchment scales, assessing the performance of existing SWC measures would give the opportunity to identify the limitations and provide hint for improvements of SWC. The assessment targeted on the technological characteristics (design and layout) of the terraces (Fig. 3). For this reason, the layout and design characteristics of the terraces were collected for all terraces from three case-study catchments in the watershed. Fifty-eight individual farm plots were taken to measure length, width, height, spacing between terraces, and number of terraces. Layout and cross sectional characteristics of terraces were assessed and discussed with respect to technological effectiveness and land users' perspective. Terrace characteristics were compared and evaluated against the recommended design and layout specifications in the implementation guideline reported by Hurni (1986).

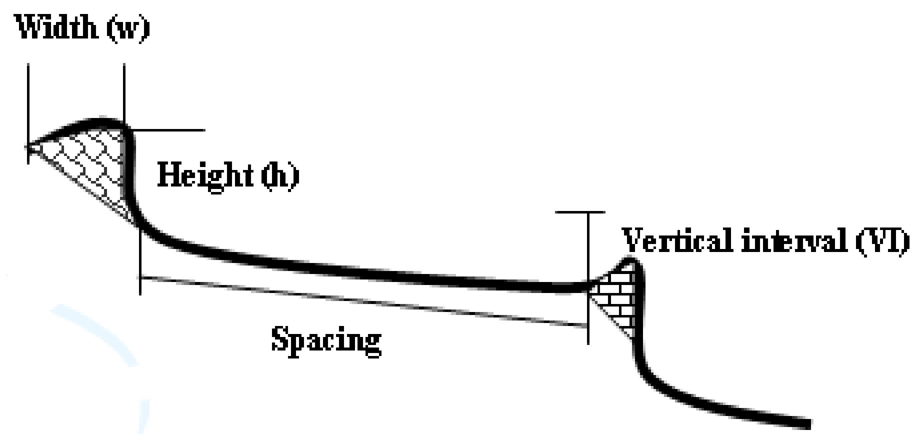

Fig. 3 Layout of stone terraces

4.3 Rainfall Measurement

In order to characterize the spatial and temporal distribution and its amount, rainfall was recorded at three case-study catchments (Chira Kiltim Sebari, Chira Godguadit, and Embes Tig) using calibrated cylinders and using rain recorder (Fig. 4) at Shembekit.

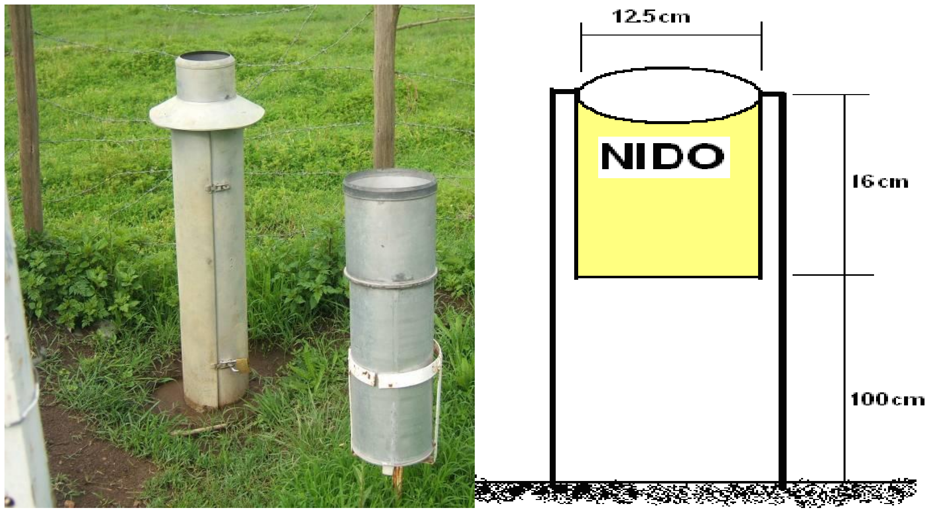

Fig. 4 Rain gauge and calibrated cylinder used for rainfall measurement

5. Results and Discussion

5.1 Rainfall Characteristics

Total rainfall recorded in the season (June- September 2008) was about 855 mm. The daily rainfall recorded in 2008 from rain gauge station at Shembekit (2405 m a.s.l) and from calibrated cylinder installed at the case-study catchments showed that the rainfall was highly variable within the watershed area and indicate the effect of altitude on rainfall distribution (Fig. 5). As it is shown in Fig. 5, the amount of rainfall decreased from the upper part of the watershed towards the reservoir at the outlet of the watershed. The high amount of rainfall associated with the steep slope gradients resulted in high soil erosion and led to further degradation.

Table 1. Rainfall amount during rill survey period

Year	Sites (altitude)	Number of rain days / storms	Total rainfall (mm)	Maximum daily rainfall (mm)
2008	Embestig (2370 m)	26	567	39
	Godguadit (2420 m)	29	578	48
	Kiltimsebari (2555 m)	28	754	48

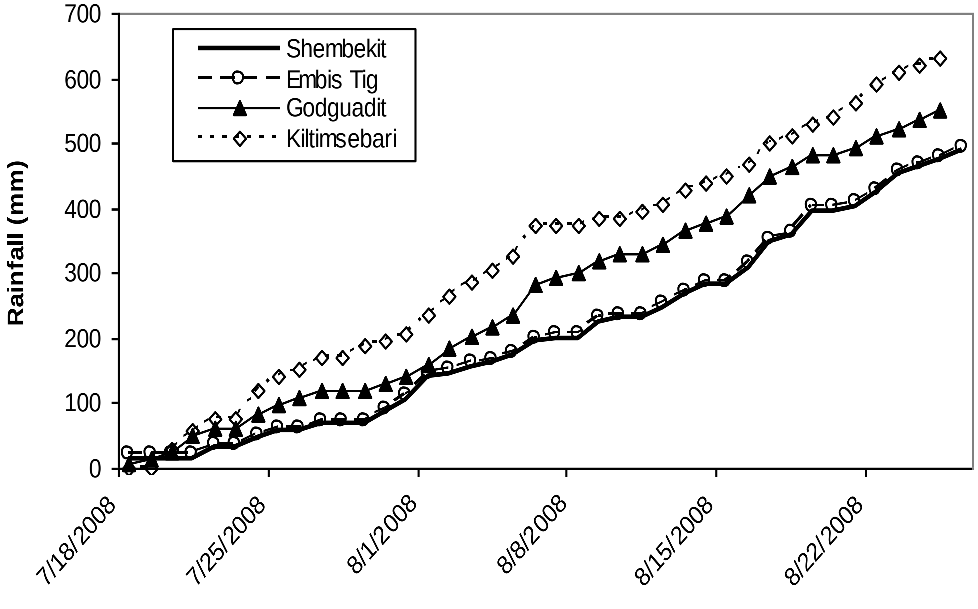

Fig. 5. Cumulative daily rainfall distribution (July- August 2008) at different sites within Angereb watershed

5.2 Farmers' Perception on Erosion Problem and its Impacts

Farmers recognize that erosion results in yield losses but also anticipate yield increase due to introduction of conservation measures. Farmers see the movement of soil from place to place as a result of deposition, and could see small rills. They see the development of gullies by water erosion. The question is whether they consider this process as one of the top production problems and give attention to minimize erosion. Some farmers may have deliberately over-estimate erosion, possibly because they hoped it would enable them to participate in some subsidized conservation program. Farmers explained impacts of soil erosion and soil conservation with respect to production trends and environmental damages. They realized the greater impacts of erosion when extreme erosion events occur in the locality. Erosion damage indicators such as big gully formation, fall of trees, damage of bridges, flooding and loss of animals are common damages recorded during extreme events. There are also experiences on the effects of erosion at plot level. For example, in less than ten years period about 50-70 % crop yield reduction is estimated by farmers on erosion prone fields as a result of water erosion. The farmers also provided relative order of magnitude for different crop cultivation practices susceptible to erosion. These practices aggravate erosion depending upon the time of cultivation, crop cover condition and associated management practices such as tillage frequency and trampling by animals.

Table 2. Soil erosion impact indicators (farmers' view)

Indicators	**Measurement of indicators**
-Direct erosion impacts	Heavy soil erosion and gully formation, loss of animals, fall of trees, and damage to terraces
-Sediment storage capacity of newly constructed terraces	Filled within 1-3 years or 2-5 years
-Soil depth	20-50 cm
-Crop yield reduction	50-70 %
-Crop cultivation systems	Teff>Faba bean>Barley> Wheat>Fallow; Or Teff>Barley> Wheat>Faba bean >Fallow; Or Barley>Wheat> Faba bean>Teff >Fallow
-Abandoned crop varieties	Barley landraces, Field pea, Rye, *Nug* and sorghum bicolor
-Future production potential of the land without fertilizer application	Without fallow lasts only for 2 years and with fallow lasts for 2-4 years (maximum not more than 5 years)

5.3 Farmers' Erosion Indicators

There is an increasing need for assessing indicators for land quality. At least three indicators can be of value in indicating the quality of land: stability of plant production; in the form of crop and pasture yield assessment from year to year; visible signs of land degradation as evidenced by excessive erosion and runoff, declining biodiversity and biomass; and what farm families themselves perceive as a change. Different measurable erosion indicators give evidence for erosion hazard or its impact. Especially in the case of field erosion assessment simple and combined indicators where many of the measurements can only be easily described and understood by farmers is important. This participatory erosion assessment approach has promoted the use of erosion indicators, with the active input of farmers' experience. Therefore, it addresses how farmers' erosion indicators can be used to obtain a fuller understanding as to whether erosion is happening. While each indicator has its own attributes and applications, several indicators together can piece together a far more comprehensive and consistent picture of erosion along the topo-sequence and the whole catchment. Different applications of erosion indicators are highlighted here:

- to show both the process and likely cause of land degradation through time
- to provide evidence and magnitude of erosion
- to assess performance of soil conservation and identify improvements

- to bring individual indicators together for comparative and overall assessment, including how to develop a procedure for getting an overall picture to assess and evaluate erosion as well as to plan SWC.

Farmers have different erosion indicators that indicate the extent and distribution of local erosion problems. Among many indicators farmers listed out the most common ones that often used to describe the severity of erosion and/or degradation at individual plot as well as catchment scale. Seasonal erosion indicators have not often perceived by farmers as erosion problem. Farmers usually do not notice the long term consequences of the seasonal erosion processes in the form of rill erosion, tillage erosion, ditch erosion, etc. On the contrary, those indicators such as gullies, land sliding, yield reduction, flooding, soil depletion, etc., which have already brought an economical and environmental damage to the locality, were easily realized by farmers, even if these are beyond their capacity to control and costly. Farmers have given priority to do control measures for such long term erosion indicators rather to prevent the seasonal erosion indicators before developed to uncontrolled stage. Out of all indicators most farmers mentioned those which have brought an economic consequence in the income of household and that lead to major environmental problems in the area. These were yield reduction, gullies and land sliding for losing their land, loss of trees for fuel wood and construction, pasture yield reduction to feed animals, etc. Historical development of erosion in the catchments was assessed by the local indicators such as change in soil surface around trees and big stones, and traditional bunds left inside cultivated plots; tillage erosion apparently observed underneath the terraces. A complete picture is only available by, for example, examining plant growth on the eroded soil; rill channel development; and, crucially, by observing and recording the sediment deposit on terraces, check dams and outlet of ditches.

Farmers provided the following common erosion indicators on cultivated fields:

- Exposure of crop roots on the surface; variation in crop yield; change in cropping pattern
- Soil texture change to gravel or rock fragments
- Exposure of rock surfaces, surface soil wash and rill channels
- Gullies and land sliding
- Sediment deposition behind SWC structures and plot boundaries
- Erosion and deposition on traditional ditches and gullying at the outlet of the ditch
- Decrease in the soil surface level surrounding big stones and tree mounds
- Tillage erosion

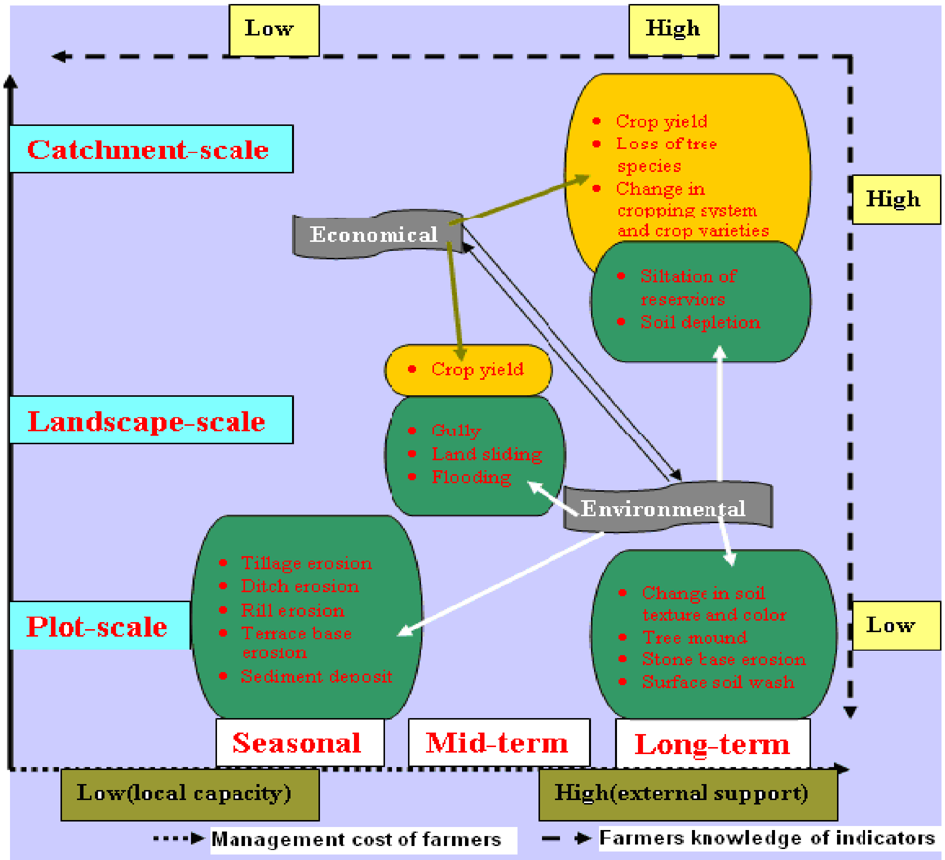

Fig. 6 Spatial and temporal classification of indicators categorized for farmers' knowledge and capacity

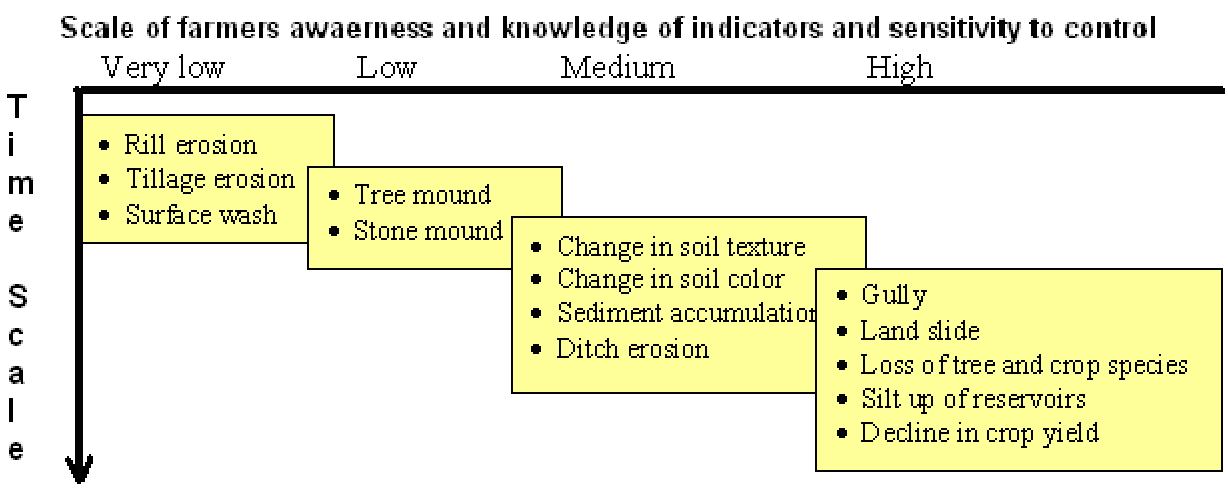

Fig. 7 Classification of local erosion indicators

5.4 Qualitative and Quantitative Assessments of Erosion Indicators

- ***Sediment accumulation behind stone terraces***

In the study catchments, stone terraces were common practice in the steep slope lands. The terraces themselves commonly integrated with a fast growing shrub, '*embuacho'* and annual local grasses cut to feed animals in the rainy season. Accumulations of sediment behind terrace structures were a useful indicator that soil movement has taken place in the field, and that, if it were not for the terrace, soil would have been lost beyond the field. A typical example is shown in Fig. 8, where the sediment trapped by the constructed riser of the terrace were measured to give an assessment of the minimum amount of soil that has been lost from the open space between terraces. The assumption here is that the material trapped has been eroded from the terrace area because of the land use, slope, terrace damage, and/or other inappropriate management practices. Despite of the complete silt up of the storage basin of terraces, on average 20-75 cm accumulation of sediment behind terraces was recorded from the sampled terrace structures. According to the sample data, the initial storage capacity was silted up within 1-5 years depending on sources of sediment, slope of the field, and terrace spacing and its design storage area. Most of the terrace capacity was silted in one season, whereas in very limited cases high seasonal accumulation of sediment was measured from some well constructed terraces. However, it is useful to view the supposed eroded soil through the eyes of the farmer because:

- after a few seasons, the soil close to the terrace is relatively rich in organic matter as well as being deep; hence the crop yield is comparatively high at this position;
- meanwhile, the farmer harvests grasses to feed their animals;
- after some years, when the terrace filled with sediment, the farmer remove the old terrace, and plants with crops in the accumulated rich soil; at the same time, a new terrace is constructed some distance down slope from old terrace position.

Fig. 8 Accumulation of sediment behind erosion control structures

- ***Tillage erosion***

Tillage has made annually using *maresha*, a wooden plough pulled by pair of oxen. A typical indicator of tillage erosion was clearly observed beneath the terrace where the soil surface is significantly lower than the base of the terrace since the construction of the terrace in 1991/92. With the tillage practice on steeper slopes, the surface soil was washed down slope. According to Nyssen et al. (2000), tillage translocation has contributed half of the sediment accumulation behind newly constructed stone bunds in Tigray area. On slopes steeper than 15 %, all soil is thrown to the lower side of the tillage furrow (Nyssen, et al, 2000). During the last sixteen years, since the construction of new terraces in the study area, the contribution of tillage erosion was in the range of 15-65 cm reduction of surface soil underneath the terrace structure (Fig. 9 and 10). This means there was an estimated annual tillage erosion range of 1-4 cm close to lower-side of terrace structures. Unlike the results obtained by Nyssen, et al (2000), on the steepest slopes the amount of soil moved by tillage beneath the stone terraces was low, because it is difficult to operate the plough with the oxen very close to terrace structures. Moreover, assessment was made at point depth samples rather than the down slope areal samples. Any way the assessment result has provided that we have a situation where erosion has been aggravated by the farmer unnoticeably. The answer as to whether the farmer perceive tillage as an erosion problem must, therefore, depend upon the farmer perspective through which the judgment is made. In the study area, farmers were less aware and may not consider the soil movement by tillage as an erosion problem.

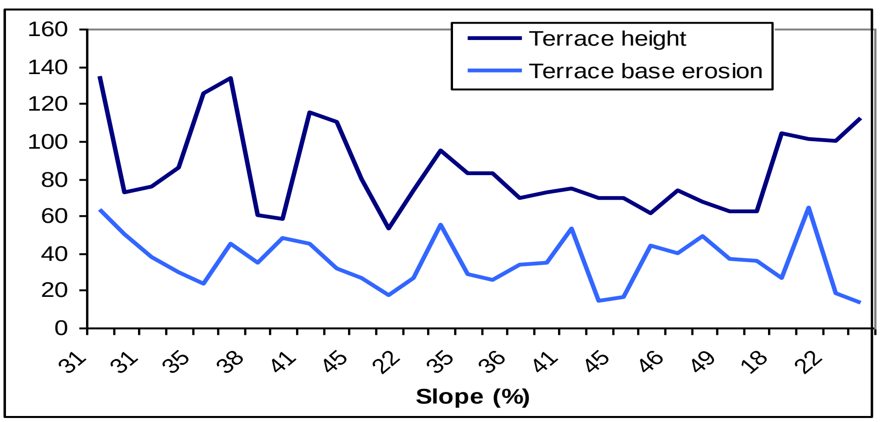

Fig. 9 Erosion underneath the terrace structure due to tillage

Fig. 10 Evidences of tillage erosion underneath stone structures

- ***Traditional ditch erosion***

On most of the farmers' field, farmers have constructed a small drainage ditch across the slope to protect the lower field from concentrated runoff during heavy storms. The farmer has to construct this drainage ditch each year randomly on the plot. It is obvious that sediments eroded from ditches and accumulated down slope were common indicators of erosion on farmers' field (Fig. 11). For example drainage ditches in the case study field plots were constructed with an average gradient 4-7 %. This implies that a large amount of sediment has been washed completely out of the field and sometimes the runoff discharged from ditches damage terrace structures and formed gullies down slope.

Fig. 11 Runoff erosion due to traditional ditches inside farms

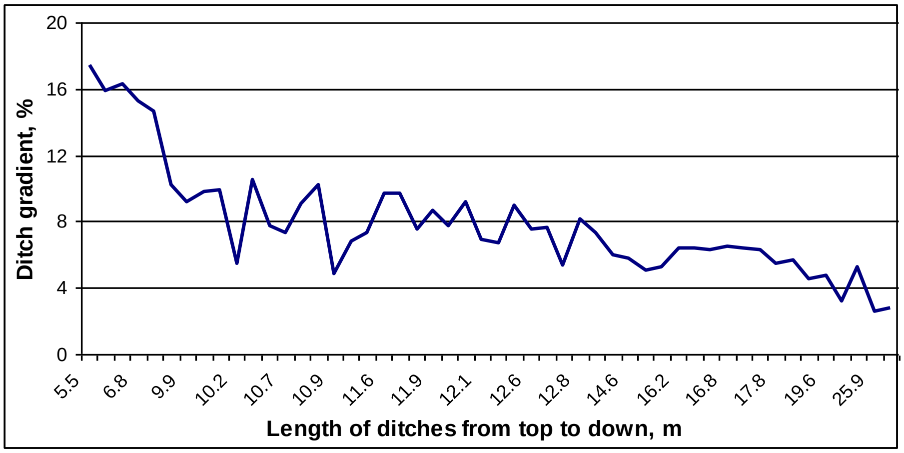

Fig. 12 The change in gradient of ditches along the longitudinal section of the ditch

- ***Yield reduction and variation in crop growth***

Farmers have experienced variation in crop growth and yield reduction in the area between terrace structures. This is the most frequent indicator of farmers to explain the problem of local erosion. Extreme erosion damage on shallow root crops expose the roots on the surface by which the land users can easily perceive and aware of erosion at the first stage. Subsequent erosion causes significant within-field variation of crop growth condition, where the upper parts are generally producing the poorest. At the top of the plot, plants were stunted and yellow-looking. Towards the lower and middle parts of the field some of the plants have a purplish color on new leaves, but those plants growing in the sediment accumulation along the boundary were vigorous and deep green in color. Crop production monitoring within the terrace area has clearly indicated the yield reduction over the slope length (Fig. 13). It was also pointed out by farmers that 5-7 % annual yield reduction was observed on erosion prone fields. Based on quantitative crop yield results from other studies, the yield variability in the terrace area has showed the impact of soil erosion over the slope length. There has been a non-linear increase of yield from top to bottom position. About 10 to 46 % yield increase at bottom position was obtained over the top position. Moreover, change in the cropping pattern to adapt the level of soil degradation is another local erosion indicator for farmers. Several of the barley landraces of better productivity were abandoned in the production system as a result of the change in the soil function. Among many of the locally named barley landraces, *Temej, Awura gebes, , Worehimen,* and others such as *Aja, Zengada,* and *Dagusa* landraces were some mentioned by farmers. On the other hand, crops like lentil and fenugreek were adapting to degraded and depleted soils.

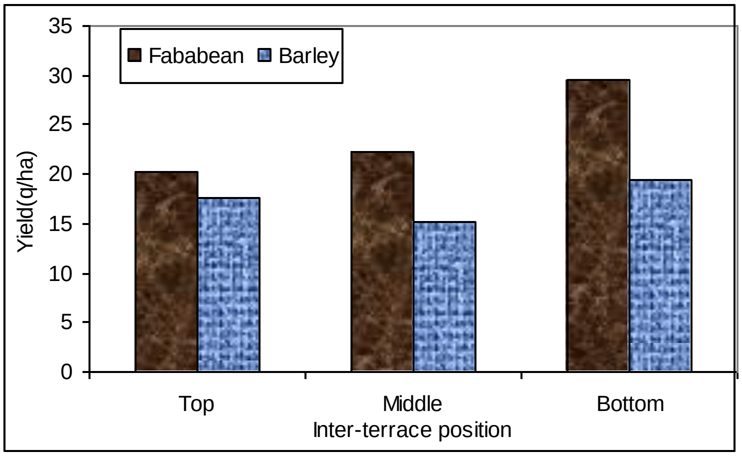

Fig. 13 Crop yield variability over slope length in the inter-terrace area (Gizaw, unpublished)

- ***Change in Soil depth* and *soil texture***

Soil depth is gradually become very shallow, averaging only between 5 to 100 cm. Soils with very shallow depth below 20 cm has changed into gravel texture and reddish yellow in color. The farmers were getting worried about this part of the field and have noticed the soil getting lighter and sandier. Farmers tried to cope up problems of soil depletion by growing crops which adapt to shallow soil depth and rock fragment textured soil, such as lentil, fenugreek, and sometimes meant for pasture production. They were struggling to produce food on this part of the land even though they are aware of the problem. However, simple analysis on the cost and benefit can suggest the need to change the land use and/or production system to profitable land resource management options.

- ***Tree mounds, expose of tree roots, and permanent stone mounds***

There are several trees within and around the catchment that have been left. Tree mounds were apparent, indicating that the surface of the soil in the field became lower because presumably topsoil has been washed off since the field was opened for cultivation. From field sample assessment, the mounds range from 20-170 cm in height above the surrounding soil surface that clearly shows the long term soil degradation process by tillage and water erosion. Longer effects of degradation process results in the exposure of deep root system of the trees that is quite a good indicator of local erosion. Absence of several indigenous tree and shrub species and existence of newly adapted shrubs was other indicators of environmental change.

- ***Permanent stone mounds***

Group of farmers were asked to recall about the historical development in the soil surface change surrounding big stones available in their plots. Taking farmers response as a reference few sample measurements were conducted for the estimation. For example, the big stone inside Tenaw's plot was totally buried 15 years ago whereas, during the study period, the surface was reduced by an estimated height of 60-70 cm. Another example has indicated a height change of 100-150 cm over thirty-year period. It implies that annual surface erosion of about 3-5 cm (approximately, 300-500 ton/ha) is occurred on such most exposed spots of the field. Additional sample measurements in the height change between the ground surface and stone mound have provided evidence of significant long term field erosion. Such kind of field based erosion analysis by farmers through visits accompanied with measurements was an innovative approach to increase awareness and stimulate farmers in controlling erosion.

- ***Gullies and land slides***

Farmers are much aware of land degradation when they observe gullies and landslides despite they have less capable to mitigate these forms of erosion problems. External assistance and catchment level soil conservation planning is needed.

Fig. 14 Active gully damage and land sliding

- ***Rill erosion***

Rill erosion as indicator of significant seasonal erosion is the center of focus of the research project. Through visual monitoring of rill formation and the rill network development on agricultural fields immediately after erosive storms, it can be easily identified erosion risk areas to plan effective erosion control. Soil erosion professionals may consider erosion problem from rill channels with depth 1-2 cm. However, perception of erosion problem by farmers were realized from rill channels defined with depth more than 5 cm and length greater than 4 m. Continuous and closer field inspection will increase farmers' perception on rill erosion. In depth characteristics of rill formation and development is presented in the following sections.

Table 3. Measurements of erosion indicators (cm) at each case-study sites

Erosion indicators	**Chira Godguadit**	**Chira Kiltim Sebari**	**Arbaba Embis Tig**
Sediment deposit behind terraces (cm)	20-75	---	---
Terrace base erosion (cm)	23-63	14-55	13-64
Stone base erosion/stone mound (cm)	30-104	---	---
Tree mound (cm)	20-114	25-170	23-70
Traditional bund truncated (cm)	63-156	43-340	---
Rill erosion depth (cm)	2-16	5-20	2-24
Rill erosion width (cm)	9-93	11-68	20-133

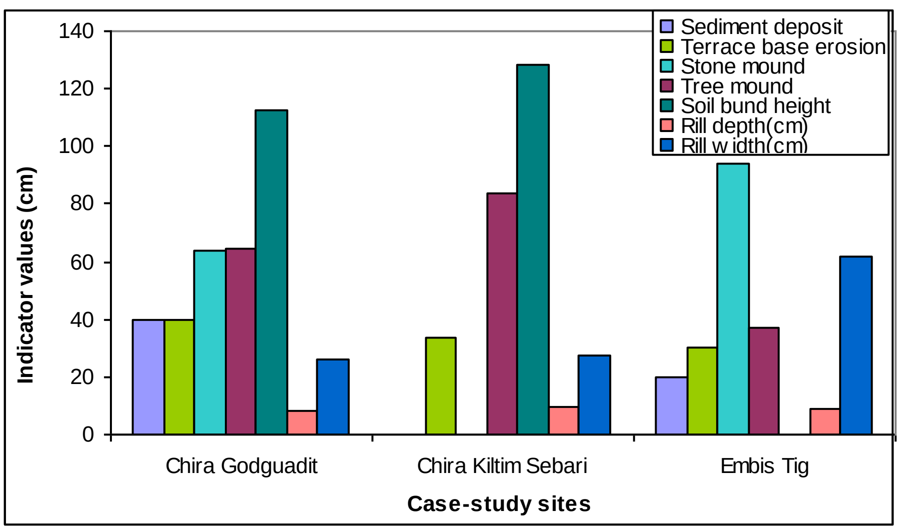

Fig. 15 Appraisal of farmers' erosion indicators in the field

5.5 Rill Erosion on Small Case-study Catchments

Rill erosion is used to describe small forms of linear erosion caused by overland flow. Rills are visible and noticeable linear erosion features easily identifiable by farmers (Herwege, 1996). Among other indicators rill erosion on agricultural lands is one that farmers can easily perceive on their plots and a suitable indicator for seasonal monitoring of erosion and for identifying limitations of conservation measures. Moreover, it occurs every year and it has wide distribution over cultivated fields more than other indicators where their occurrence and distribution is only limited to specific spot areas. As a result of its spatial distribution and formation, rill erosion leads to significant erosion damage without the notice of farmers. The magnitude and distribution of rill erosion damage are assessed by measuring the rill dimensions, count and longitudinal rill development. Based on these measurements, farmers can decide the risk of on-site and off-site erosion in order to plan and implement anti-rill erosion measures. In this study, visualizing the development and distribution of rill erosion, its causes and impacts on individual plots and over the topo-sequence was thus the concept taught and shared to farmers as a simple method for field erosion evaluation and SWC planning purpose through participatory action learning process. Thus, participatory rill erosion assessment was taken as a commendable tool for practical conservation-oriented soil erosion assessment purposes.

In Angereb, erosion in the form of soil detachment by raindrop impact, rills and gullies is widespread. The results of erosion by raindrop impact were seen in the form of erosion pavements, and sediment deposits on farm boundaries and terrace lines. Rill erosion was clear for all to see and most commonly occurred under the following circumstances: when concentrated runoff occurred on the upper source areas and discharged through series of terraces; overflow of runoff from damaged and sediment filled terraces; drainage ditches; and wide spacing between terraces. Gullies were formed mainly in natural drainage lines, along paths and high depression plot boundaries. The resulting vertical banks were also unstable and liable to subsequent land sliding where there was excess interflow of water.

The topography of the catchment at Godguadit site was undulating with concave shape at the central part. About 60-70 % of the catchment was drained by a manmade waterway (or foot path) from North West to South East direction. Manmade waterway protected the overflow of concentrated runoff to the lower fields. Runoff emerging within the fields, fragmented land units, traditional runoff ditches, and damaged stone terraces were the main causes for rill formation and its development. Godguadit catchment is generally characterized by very shallow soil depth and high soil degradation compared to other catchments. For a shallow soil depth, the infiltration is reduced and led to high amount of overland flow. Kiltimsebari catchment has linear geomorphology (linear slope) extended from top to middle of the slope and undulating topography at lower slope area. However, the middle catchment area is concave shape in the lower part. Comparatively, Embestig catchment has better soil depth and less degradation. The catchment is represented by linear steep slope. Most of the fields in the upper part of the catchment were covered with high intensity stone mulches and classified as no erosion area. However, the lower part of the catchment was affected by erosion due to the runoff generated from upslope tree plantation area located at the middle of the catchment. Rill erosion assessment was therefore made only from fields at the lower part of the catchment at Embestig (Fig. 16). Table 4 shows the average slope gradient and number and spacing of stone terraces for about 23 rill survey field plots in the three catchments.

Table 4. Characteristics of rill erosion survey plots and landscape positions at study catchments

Case-study catchment	**Landscape position**	**# of plots**	**# of terraces per plot**	**Avg. terrace spacing (m)**	**Avg. slope (%)**
Godguadit	Upper catchment	3	2-4	13.8	39
	Middle catchment	3	2-3	10.7	38
	Lower catchment	3	2-3	15.4	38
Kiltimsebari	Upper catchment	2	3-7	9.9	38
	Middle catchment	3	5-8	15.5	47
	Lower catchment	2	1-4	15.5	48
Embestig	Upper catchment	2	3-5	12.9	32
	Middle catchment	2	2-4	14.9	27
	Lower catchment	3	1-2	16.5	14

Fig. 16 View of case-study catchments: Godguadit (top), Kiltimsebari (middle) and Embestig (bottom)
(Photo by Gizaw, 2008)

5.5.1 Rill characteristics and rill development along the topo-sequence

Table 5 presents average rill cross sections and rill numbers in the surveyed fields following topo-sequence of the catchments. It should be necessary to note here that the magnitude of rill erosion does not represent the absolute rill erosion for the study sites. This study was more concerned on the relative spatial variation and development of rill erosion along the slope profile. Total number of rills was a minimum of 2 and maximum of 22 per surveyed fields. Rill depth of 3-16, 5-20, and 5-25 cm and width of 8-90, 10-70, and 20-130 cm were measured at Godguadit, Kiltimsebari and Embestig catchments, respectively. The average depth of rills was more or less similar at the three catchments. Significant differences were found in the width of rills which resulted in different cross-sectional rill erosion among the study catchments. On average, rill cross-sectional area of 222, 299, and 650 cm^2 were obtained at Godguadit, Kiltimsebari, and Embestig sites, respectively. The corresponding average rill density was 1.34, 0.72 and 0.15 m^{-1}. The average rate of rill erosion was 310, 236 and 79 $cm^2\ m^{-1}$ at Godguadit, Kiltimsebari, and Embestig, catchments, respectively. The occurrence of many smaller rills at Godguadit and few larger rills at Embestig was as a result of differences in local runoff source areas and slope shapes. Within field runoff concentration at Godguadit and concentrated runoff from upslope eucalyptus plantation area at Embestig, and runoff from fields and foot path areas at Kiltimsebari were the immediate causes for rill formation and spatial rill distribution.

Table 5 Average rill cross-sections and rill numbers measured from case-study catchments

	Case-study catchments		
Rill characteristics	**Godguadit**	**Kiltimsebari**	**Embestig**
Rill start from upper terrace (m)	0.62±0.29	1.32±0.37	0.65±0.80
Rill spacing (m)	0.89±0.49	1.75±1.14	8.16±2.95
Rill depth (cm)	8.14±1.21	9.69±1.27	8.92±3.62
Rill width (cm)	26.80±5.25	29.6±6.9	68.09±19.03
Rill cross-sectional area (cm^2)	222±65	299±109	650±386
Rill density (m^{-1})	1.34±0.48	0.72±0.34	0.15±0.08
Rill section erosion ($cm^2\ m^{-1}$)	310±158	236±185	79±87

As shown in Fig. 17, rill cross section and rill count development over the topo-sequence of the catchments revealed the local specificity of erosion. At Godguadit site, rill erosion was slightly increased from upper to middle catchment and slowly decreased at the lower slope of the topo-sequence. On the contrary, rill erosion was high at the middle of the catchment and low at both upper and lower slopes at Kiltimsebari catchment. Somewhat linear reduction in rill erosion and rill counts over the topo-sequence was observed at Embestig catchment. Fig. 17 indicates that rill formation and development was related to the convergence, divergence and uniformity of slope shapes associated with the geomorphology and barriers on the landscape structure. High rill development occurred on concave slope shapes at Godguadit and Kiltimsebari. Similar results were obtained from the long-term rill erosion data at Andit Tid catchment (Fig. 18). Convex slope produced comparatively less rill volume followed by linear and concave slope. Concave slopes were more susceptible to rill formation than convex and linear slope shapes. Research results by Moore and Burch (1986) have also showed the impact of convergence on erosion, largely through the development of rills and gullies that increase erosion compared with the divergent slope shapes. Rieke-Zapp and Nearing (2005) indicated the occurrence of deep rill incision on the concave-linear slope shape.

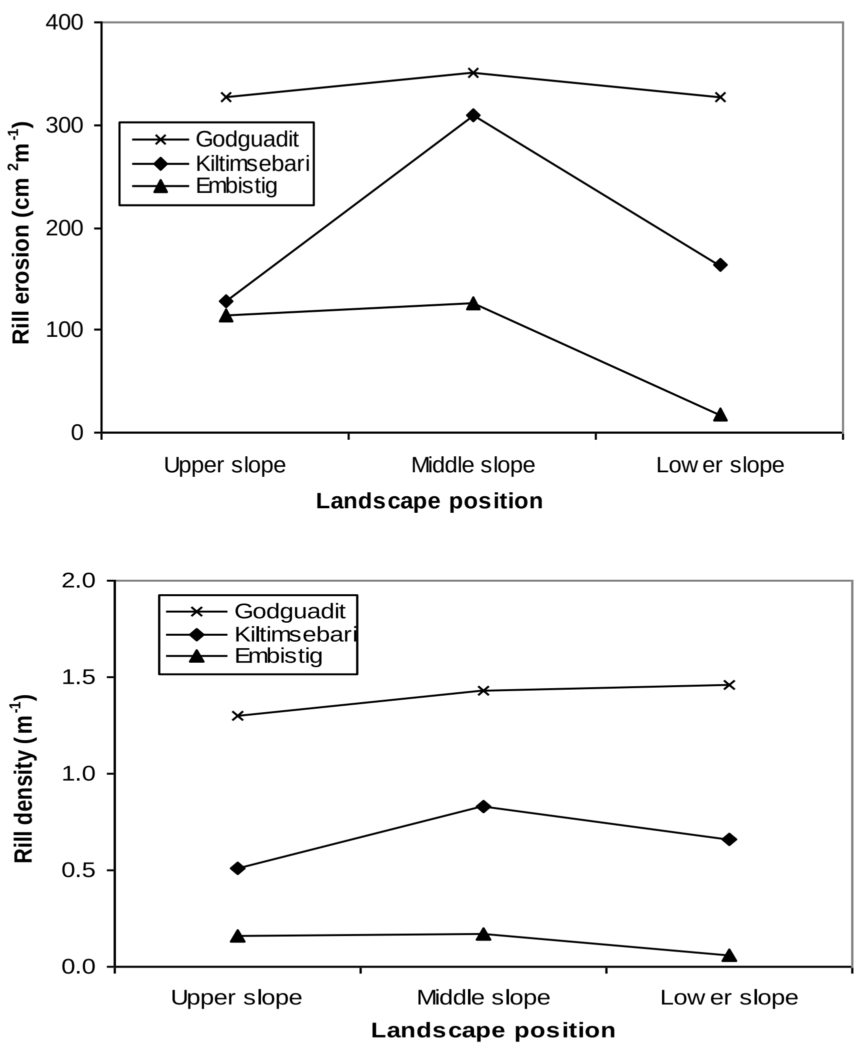

Fig. 17 Rill cross-section and rill density along the topo-sequence at the study catchments

(Landscape position refers the altitude difference namely upper, middle and lower catchment area)

The role of stone terraces at Godguadit and to some extent at Kiltimsebari was minimum compared to Embestig catchment. At Embestig, the relative uniformity in the layout of terraces along the slope profile provided comparably low rill formation at lower part of the catchment. The fact that the number of rills was small and reduced down slope suggested that concentrated runoff emerged from upper tree plantation area was filtered and obstructed by series of stone terrace structures. This has led to produce fewer rills at the lower section of the catchment. As the runoff energy is dissipated on terrace elements (Gimenez and Govers, 2002) the shear stress is not effective for rill channel formation. The scouring capacity of the runoff was limited by the buffering effect of terraces. At Kiltimsebari, foot paths and fallow lands at the middle position of the landscape were sources of concentrated runoff which resulted in the formation of many rills on fields at the middle catchment. On the lower part of Kiltimsebari, rill development was decreased because of the presence of depression areas at the lower catchment.

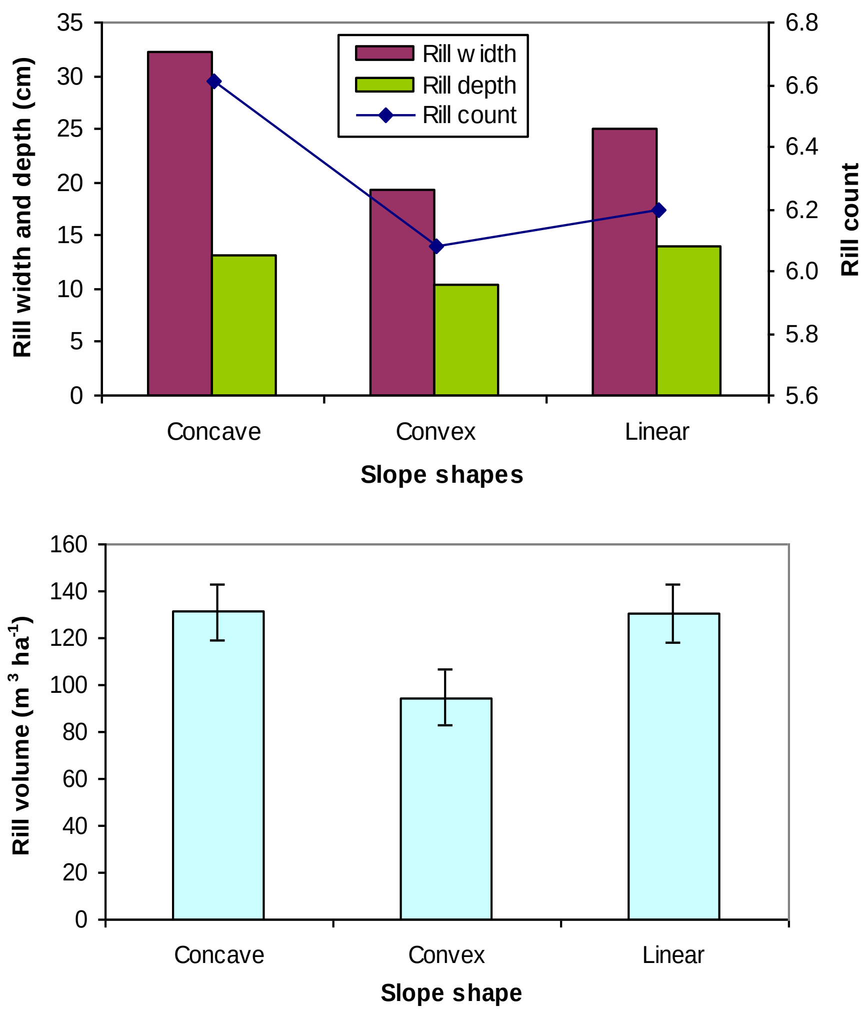

Fig. 18 Characteristics of rill erosion related to slope shapes (Source: SCRP Andit Tid data base)

The concavity and convexity of the individual fields and runoff source areas (outside and within the fields) controlled the spatial rill formation and development over the topo-sequence. The presence of conservation terraces, foot paths and waterways inside the catchment has also played a great role for the longitudinal rill development by diverting or dissipating the concentrated runoff. Therefore, rill formation and its longitudinal development varied depending on the specific slope shape, runoff source areas and macro-surface elements such as terracing and field boundary on the landscape which directly affected the runoff concentration and its longitudinal redistribution.

5.5.2 Rill formation and development on the intra-terrace area

This section presents the relative differences of rill erosion in the area between terrace structures to characterize spatial rill development, assess the efficiency of existing terraces against rill formation and describe associated causes. Fig. 19 illustrates rill cross sections and rill numbers surveyed at three relative positions on the area between terraces averaged over the landscape positions. Similarly, Fig. 20 shows rill erosion and rill density results at top, middle, and bottom terrace positions for individual surveyed fields (note that the order of field numbers increase from upper slope to lower slope). There was a local specific pattern of rill cross section erosion and number of rills for each case-study catchments. At Godguadit site the rill cross section erosion and rill density measured at the top section of the terrace area was decreased down slope. On the other hand, on the middle and bottom intra-terrace positions, both rill erosion and rill density was linearly increased down slope. At Kiltimsebari site, except on the concave shape part of the catchment, rill erosion and rill density linearly increased from top to bottom position of the intra-terrace area. Rill cross sectional erosion at Embestig however, decreased from top to bottom in the area between terraces particularly on the upper and middle part of the catchment. Even though there was more or less similar terrace spacing in the catchments, the pattern of longitudinal rill erosion development in the area between terraces was dynamic and varied from catchment to catchment. Monitoring the quantitative rill cross section and density of rills within the terrace area following the topo-sequence indicated the combined role of terrace design and layout and landscape structures, slope shapes, and erosion source areas. Rill erosion and its development at the upper slope area were controlled by the runoff concentration from source areas. In addition, slope and slope length of the fields controlled rill erosion variation within the terrace area.

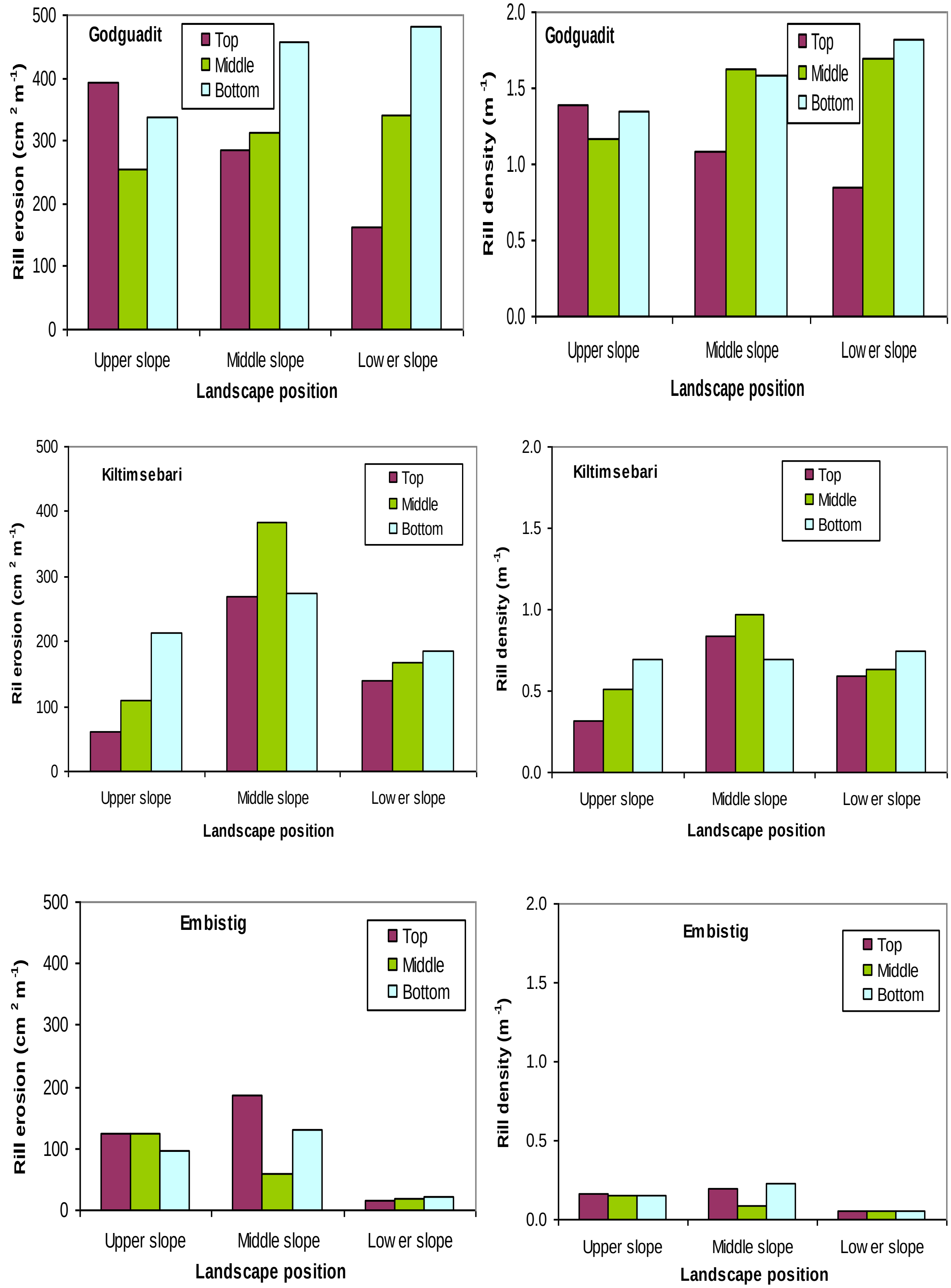

Fig. 19 Cross sectional rill erosion and rill density on landscape positions and on intra-terrace area.

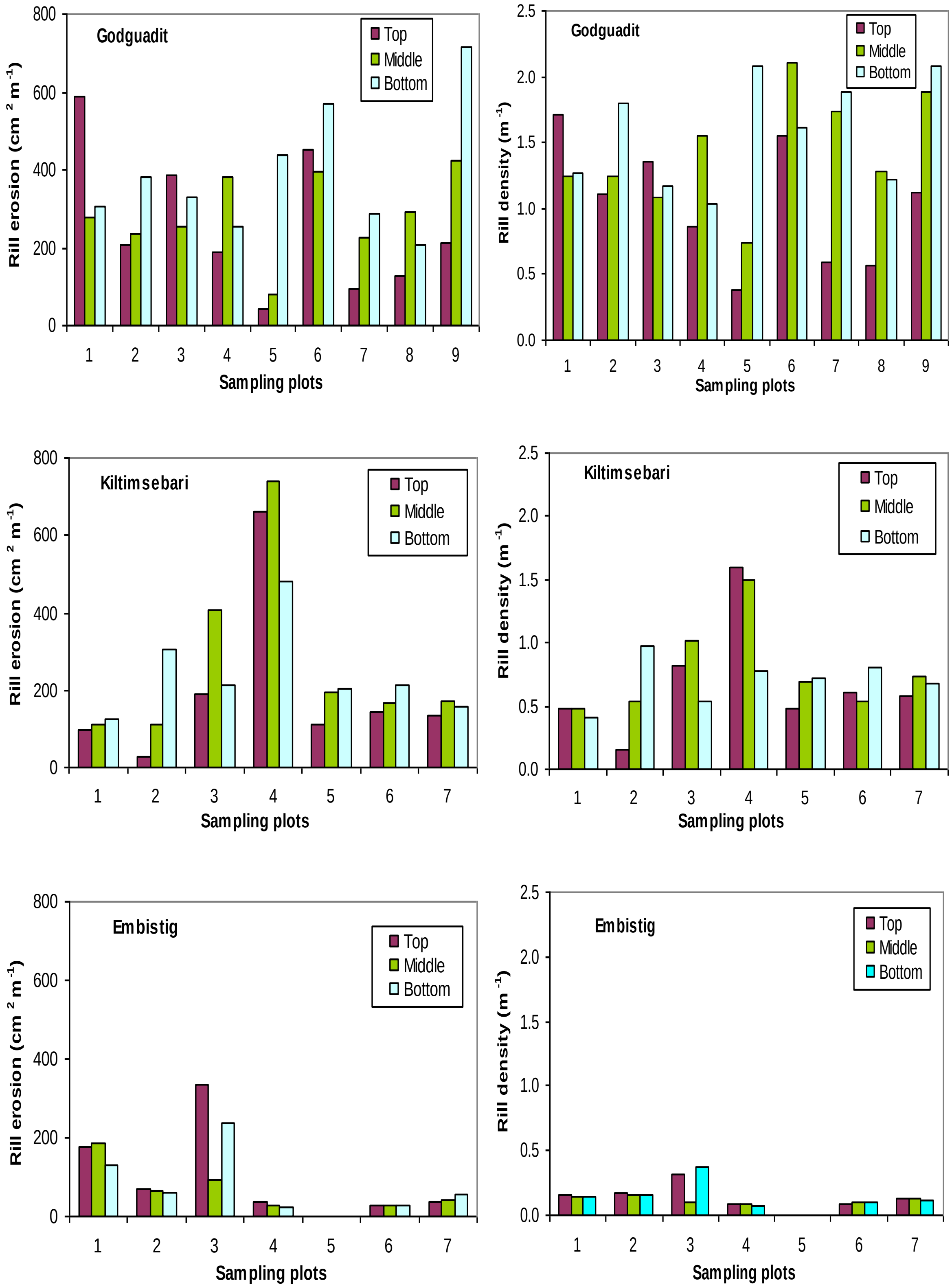

Fig. 20 Rate of rill erosion and rill density measured on top, middle and bottom positions of terrace area (Top, middle and bottom defines the relative position of the area between two terraces)

Temporal rill development was monitored three times following erosive rainfall events during July to August 2008. Fig. 21 presents cumulative rill cross section and rill density measured at the case-study catchments. Increased rill erosion and rill numbers were observed with rainfall at Godguadit and Embestig sites. However, at Kiltimsebari catchment, large amount of rill erosion was surveyed during the second rill survey period. It was decreased during the third survey period due to crop cover that reduced further rill formation.

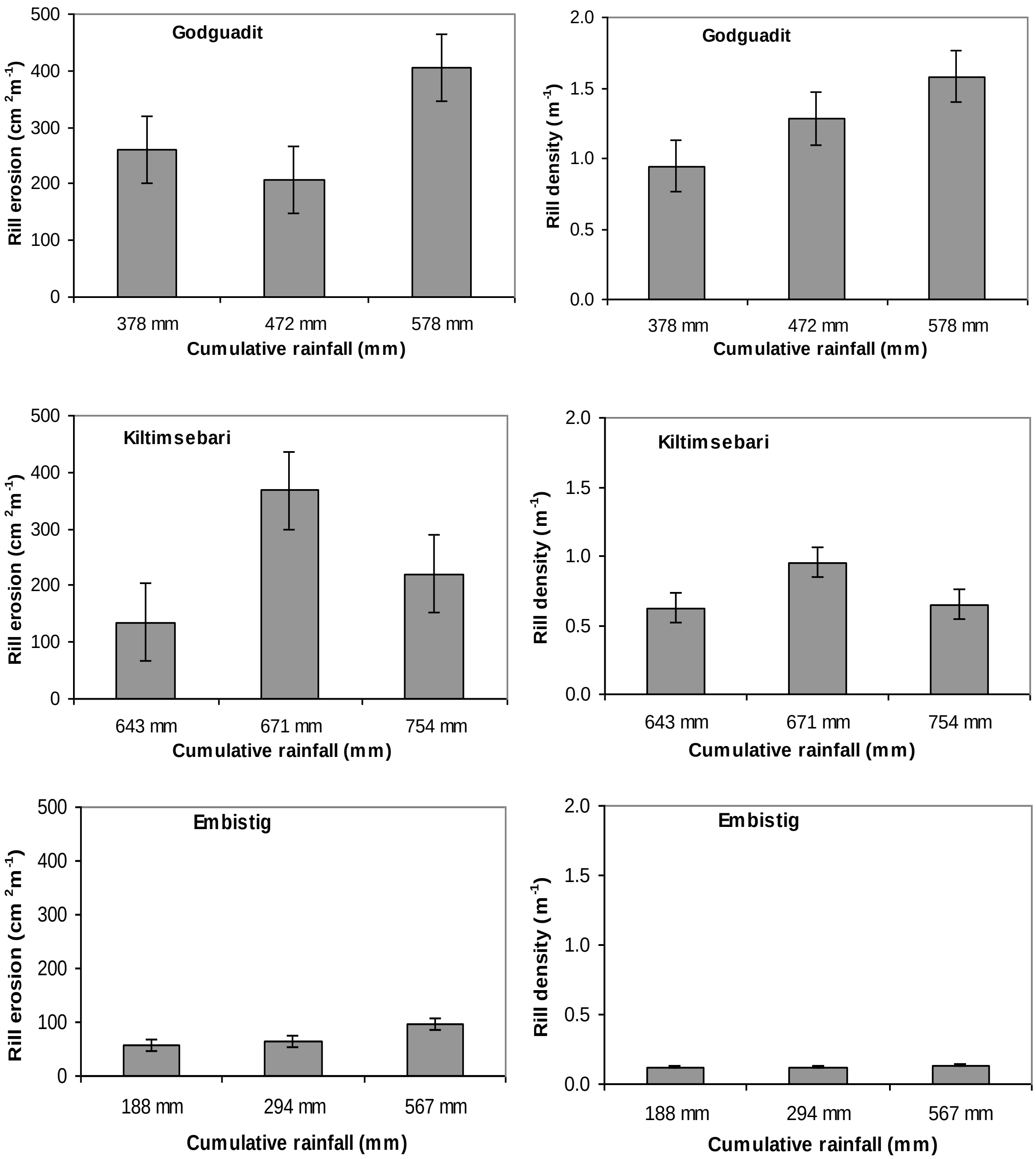

Fig. 21 Temporal variation of rill erosion and rill density measured in July to August, 2008

5.6 Assessment of Stone Terraces on Agricultural Fields

The most commonly practiced mechanical SWC measures in the study area are introduced stone terraces and traditional ditches. Stone terraces were widely practiced and distributed all over the cultivated plots in the study catchments. No farmers experience was observed in supporting the mechanical structures with biological ones except that local shrubs called *"embacho"* grow naturally along the terrace lines. Even if this shrub species support the terrace to retain the sediments, the farmers have reported a claim that the species occupied cultivated area and encroached into the cultivated land. All farm plots (average area of 0.33 ha) have at least one and a maximum of eight terraces inside the plot provided that the effectiveness of the terraces is questionable. Almost all the terrace structures were silted up and damaged due to runoff overtopping the terraces, and improper tillage underneath the terrace. There was no common and standard terrace layout and design for the same slope and soil conditions. As a result fragmented terraces were a common cause for erosion damage within the plot and adjacent fields. Assessment of soil conservation terraces has been carried from both technological and socio-economic point of view. Technological assessments are based on scientific evaluation of the layout and design characteristics of the terrace structures. The farmers' assessment was constituted from the context of the farming system and social and cultural interests and preferences. As a result, assessment and evaluation by different actors will definitely follow a different set of measurements and indicators with some in common.

5.6.1 Technological assessment of stone terraces

The objective of terracing is to reduce soil loss and retain the soil in its original place. This could be true by depositing washed soil particles in the open area between terraces so that a bench is formed. In his economic evaluation of soil and water conservation measures, Graaff (1996) defines to what extent a measure is effective depends on the degree to which it contributes to its objective of reducing soil, nutrient and water losses. And to what extent a measure is efficient depends on the response to yields or to the increased utility that is brought about by the amount of soil, water and nutrients retained, which could also minimize downstream effects. Assessing the effectiveness of SWC measures, particularly the stone terraces, was therefore made from the point of view of reducing soil loss related to layout and design as well as sustainability aspects of terracing. The design and layout of a terrace involves the proper spacing and location of terraces, the design of a channel with adequate capacity, and development of a formable cross-section. Terrace spacing should not be so wide as to cause excessive rilling and the resultant movement of large amount of soil into the terrace channel.

The runoff from the terraced area should not cause overtopping of the terrace, and the infiltration rate in the channel should be sufficiently high to prevent severe damage to crops (Taffa, 2002). Technically the effectiveness of terraces in this study was measured by: the storage capacity, cross section of a terrace, terrace spacing, and terrace density indicators.

Storage capacity of terraces: In the study area, existing terraces were reconstructed in 1993 with an approximate height of 25-30 cm and 50 cm on the upper and downside respectively. Farmers responded that all terraces were appropriately designed with adequate capacity during first construction; however, the channels were damaged due to the frequent tillage made close to the terrace. According to farmers' response the storage area of the terrace structures were filled up within estimated 2-4 years after construction. Without annual maintenance of terraces, tremendous soil sediments were washed in the remaining years. Out of the surveyed fields when assessment was made in 2008 rainy season only 10 % has shown stored sediment behind the terraces. A similar survey of terraces in 2007 rainy season has shown only 20 % of the surveyed terraces had significant storage of sediment in the season. From the intensive assessment of all terraces in the study catchments it was observed that on steeper slopes the storage capacity was reduced. In most of the surveyed fields a clearly defined storage area was not observed. It is only those terrace structures situated in the down slope of the landscape and relatively on the flat segment of the plot had retained the sediment washed from the terrace area. It is because of the reduced runoff velocity in the moderate slope section near to the terrace.

Cross-section of a terrace: As one element of terrace design, cross section of a terrace was taken as another indicator in evaluating terrace performance. Inadequate design in the cross section of terraces leads to the overtopping of runoff, instability on steep slopes and easily liable to mechanical damage by animals. Assessments in the riser height and top width of terraces have shown that the existing terraces will not be more effective unless immediate improvements should be taken. For the reason that the foot of the terrace structure was tilled every season, the structures were collapsed on most of the sampled fields (see Fig. 22). Height measurements from the ground surface to the terrace base and to the top of the terrace are indicated in Fig. 23. This implies the height of terrace structures from the ground surface exceeded the height during establishment. There was more than 50 % increase over original terrace height due to terrace base erosion. According to the guideline (Hurni, 1986), the design height under the existing terrace condition was exceeded due to tillage underneath the terrace structures (light shaded area in Fig. 24). The existing width of terraces was about 50-70 % of the smaller value of the design specification (i.e, 100 cm). The terrace cross section was therefore smaller than the design value indicated in the guidelines because of damage caused by animals, low maintenance, and instability. In conclusion the terraces in the study area were not in a stable condition to perform its function properly. As per the discussion with the farmers, maintenance and improvements in such condition became difficult. On steep slopes the risers become very steep and it is impossible to add stones and maintain on the top. Either a supporting terrace on the foot of the original terrace or complete removal and new establishment were the options suggested by farmers. But in a situation where sediments were accumulated over the years and formed a heap, the option of complete removal of terraces was not supported by majority of the participant farmers. Farmers believe that removing the old stabilized terraces could bring more soil loss by washing the accumulated sediments farther down slope.

Fig. 22 Unstable and damaged stone terraces due to tillage of the terrace base on steep slopes

(Photo by Gizaw, 2008)

Terrace spacing: There are three factors of a slope affecting erosion, namely steepness, length, and curvature. In the design of conservation structures an account of these topographic factors at various soil, land use and climatic conditions is necessary to obtain a proper layout of structures. A slope length at which overland flow becomes erosive is the critical slope length. Provided the effective slope length can be maintained below this critical value, serious soil erosion will not occur. The technique for achieving short slope lengths is to break up the hillslope into segments using terrace structures. From a technical point of view, deciding a suitable spacing for the terraces is necessary to estimate the critical slope length. Spacing between terraces and/or vertical interval was therefore taken as an indicator to evaluate the effectiveness of terraces (Fig. 24).

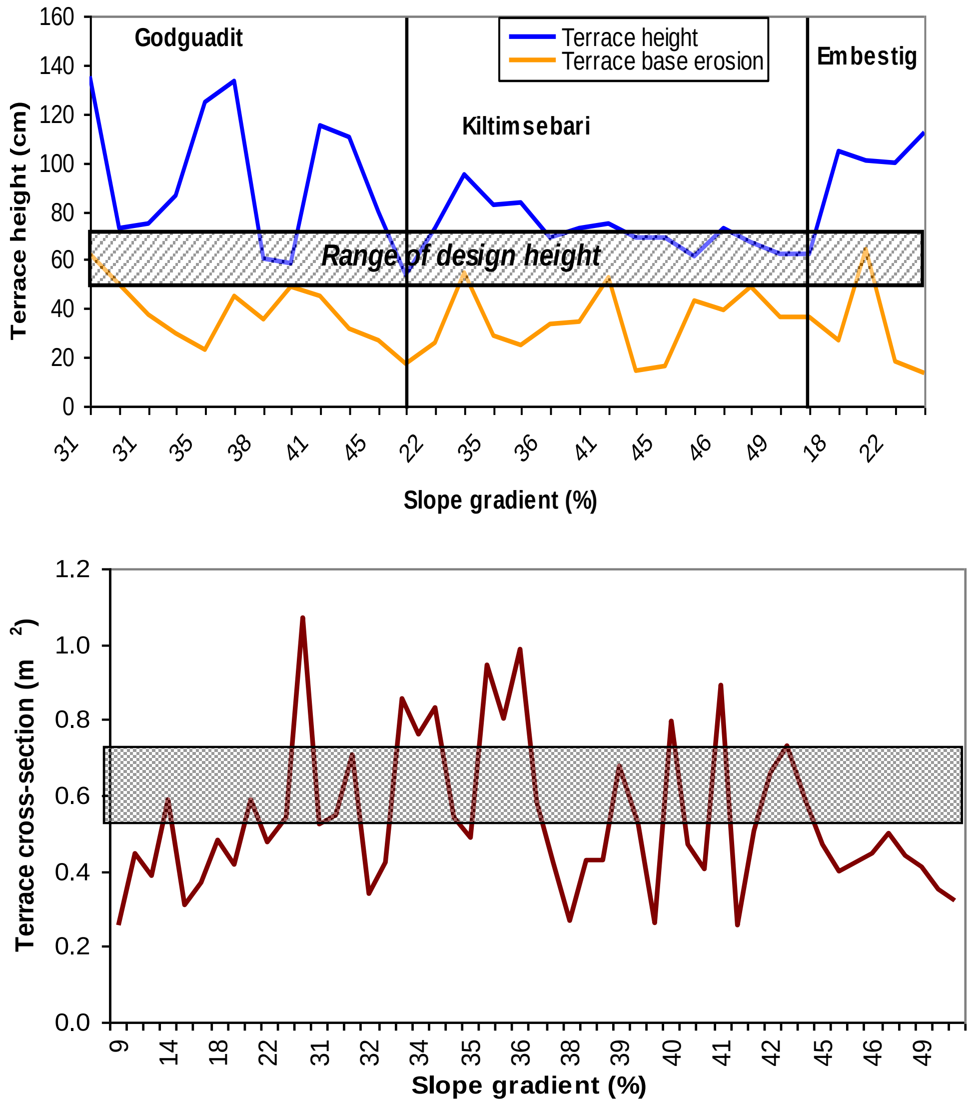

Fig. 23 Existing terrace height (top) and cross-section (bottom) in relation to the design specification (shaded part)

In principle, the spacing should decrease when slope increases. However, terraces implemented by the farmers have shown increased trend of vertical interval for steeper slopes. Similarly, the spacing was more or less uniform for slopes >30 %. The spacing between existing terraces was in between 5 to 25 m with an average of 14 m. In addition to the damaged and instable terrace structures such wide spacing between terrace structures generated greater runoff concentration that led to excessive erosion. The combined effects of smaller terrace cross section and larger spacing have reduced its effectiveness and efficiency to enhance crop production on treated agricultural lands. It has aggravated on-site erosion damage behind the structures and irreversible degradation down slope where concentrated runoff break through fragmented and defective terrace segments, and further merged with the traditional ditches. Even though this problem is the real fact at field condition, farmers did not accept narrow spacing as they believe it reduced considerable cropping area.

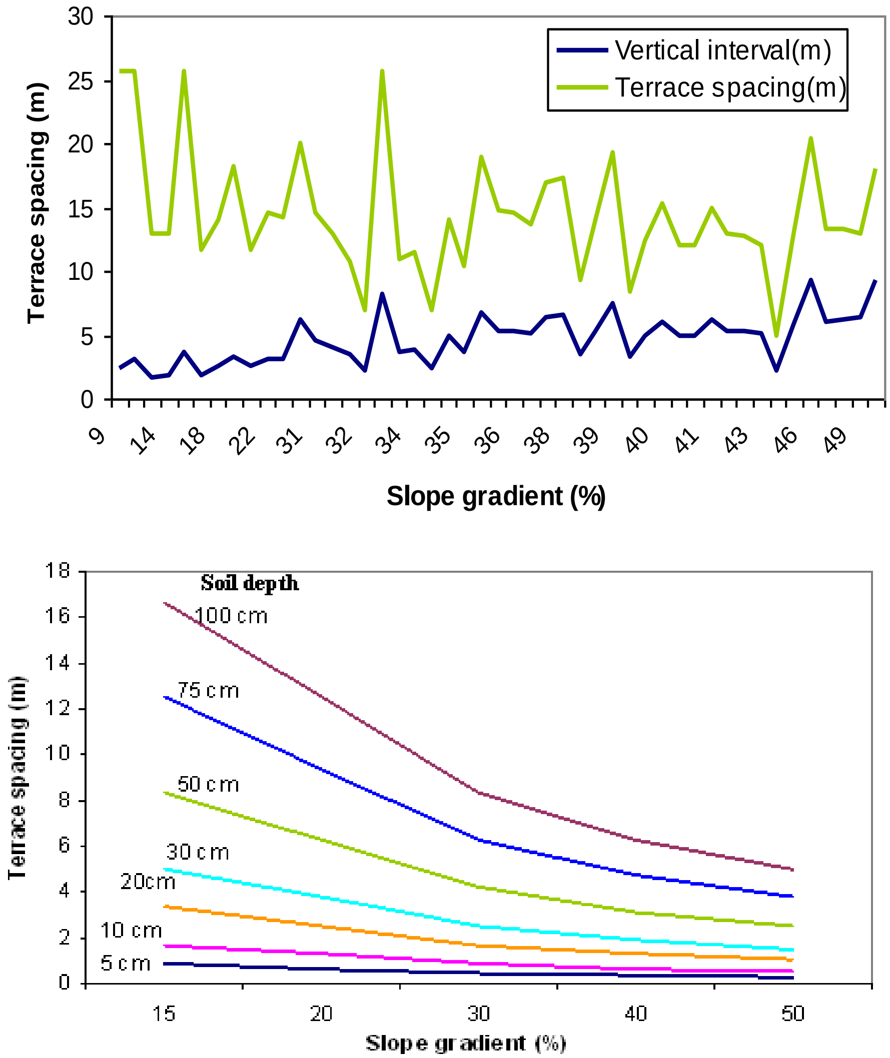

Fig. 24 Existing terrace spacing and vertical interval (top) and design spacing at different soil depths (bottom)

Terrace density: Provided that the proper cross sections of terraces are kept, the performance of terraces can also be observed by the intensity and spatial distribution in a given field or catchment area. The existing average stone terrace density (defined by terrace length divided by the area coverage) on agricultural lands at Godguadit, Kiltimsebari and Embestig case-study sites was 420, 466, and 367 m ha^{-1} compared to 506, 982, and 480 m ha^{-1} according to the design specification at 30-

60 % slope class, respectively. The terrace density was decreased with an increased in slope gradient. Under the existing terrace density, the area occupied by terraces per hectare was less than 0.5 % which resulted in approximate yield loss of 16 kg ha^{-1}. Moreover, according to farmers' estimation, the annual yield reduction per hectare was about 5-7 % due to accelerated soil erosion.

5.6.2 Comparison of terrace dimensions with design specifications

For SWC extension program, an implementation guideline was developed by Hurni (1986). The guideline provides options of technologies for different traditional agro-ecologies and land use classifications. Moreover, it presents general layout and design specifications for each type of technologies. It is the only guideline that opens the eye of SWC experts though it lacks more specific recommendations. It was therefore relevant to compare the results of field terrace assessment with the specifications indicated in the guideline. Hurni (1986) has developed a relationship of soil depth and terrace spacing for slope gradients greater than 15 %. In a situation where the soil depth was in the range of 5 to 70 cm on steep slopes, the calculated spacing between terraces was found between 2 and 8 m (Fig. 25). But the farmers did not agree and accept such spacing between terraces. Through continuous discussions and knowledge sharing at field level farmers consensus has to be made on the critical spacing between terraces. During field visits in the assessment of rill erosion between terraces, some farmers have pointed a critical spacing not less than 5 m. according to the implementation guideline 5 m critical terrace spacing was only applicable for all slope ranges with soil depth above 1 m; or for slopes less than 35 % the soil depth must be greater than 0.75 m; or for slopes less than 25 % the soil depth must be above 0.50 m (Fig. 25). Therefore, terrace spacing of 5 m can be applied only if the minimum soil depth will be 0.75 m and above. While the existing soil depth for the majority of the cultivated lands were up to 30 cm. It means that for shallow soil depths there will be a limitation of agricultural production in all slope classes unless farmers agree to construct terraces with narrow spacing. Nonetheless, further field based assessments and last long discussions with farmers will be necessary to set the critical spacing for different sets of conditions.

Table 6. Comparison of existing terrace characteristics to design specifications

Terrace properties	Godguadit		Kiltimsebari		Embestig	
	Existing terrace	Design specific	Existing terrace	Design specific	Existing terrace	Design specific
Terrace spacing (m)	14.00	2.23	13.60	2.22	15.00	2.37
Vertical interval (m)	5.10	0.82	5.40	0.89	3.74	0.83
Terrace density (m ha^{-1})	420	506	466	982	367	480
Width (cm)	65.00	100	70.00	100	54.00	100
Height (cm)	94.00	50-75	71.00	50-75	91.00	50-75
Terrace x-section (m^2)	0.62	0.5-0.75	0.50	0.5-0.75	0.49	0.5-0.75

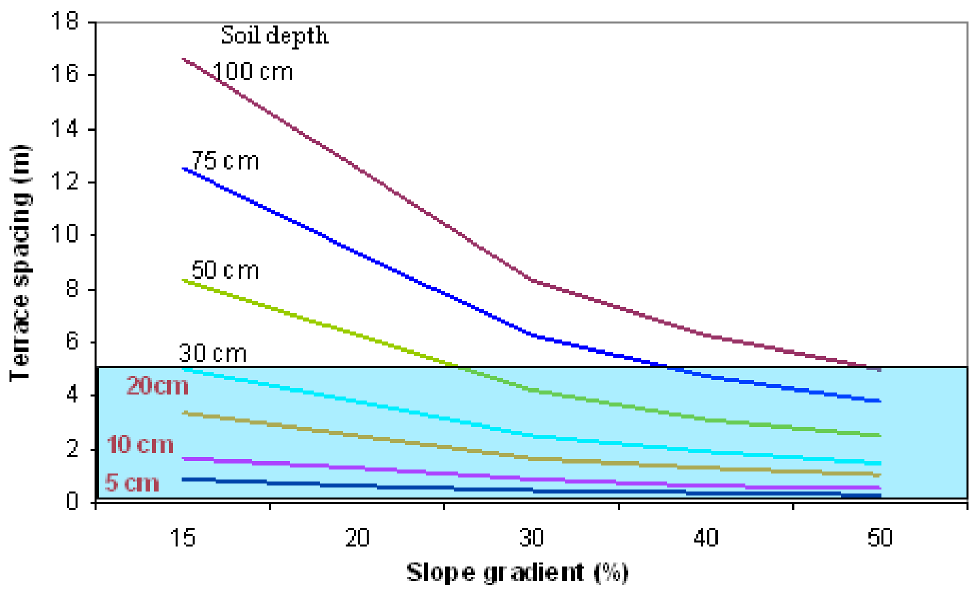

Fig. 25 Unacceptable range of terrace spacing (shaded range) from farmers' perspective

In the same manner the cross section (height and width) of terraces has to be evaluated by farmers and determined from their perspectives. Farmers have viewed the cross section from the point of stability of construction material and labor availability to construct. Stone terraces were less preferable by farmers mainly due to maintenance and labor cost aspects. Farmers low acceptance to stone terraces can be an opportunity to promote integrated measures with biological materials which are more environmental feasible and economically viable. Gradual accumulation of sediments behind terrace structures can be retained with the support of biological materials because when the sediment accumulates further the plants grow simultaneously.

Land occupied by terraces per hectare is about 15 % when terrace implementation was done based on the mentioned guideline. It was estimated about 500 kg per hectare yield loss due to the area occupied by terraces compared to 16 kg ha^{-1} under existing condition. There was an additional labor incurred due to extensive terracing while the yield loss due to soil erosion was expected to be reduced to tolerable level. More investigation is thus required from farmers' perspective by briefing the detail technical considerations in the design and layout of terraces so that they will able to set a decision system from an economic and ecological point of view. To see how effective the technical feasibility of terraces an economic and ecological impact analysis of terraces is also necessary. Comparative analysis has to be made for this purpose using simple measurable indicators such as soil loss, land fragmentation, environmental changes, crop yield, land occupied by terraces and so on.

5.6.3 Farmers' assessment of stone terraces

It was difficult for the farmers to realize the full benefits of soil conservation using terracing. Farmers asserted that it was difficult to conclude that soil erosion was controlled after their field treated with terraces. Farmers perceived the benefit of terracing. Their assessment criteria were mainly related to the immediate benefit of terracing and the utility brought about by the retained sediment; and the expenses incurred for establishment and maintenance. Crop yield benefits, the amount of labor and capital invested, and areas occupied by the structures, were the commonly indicated assessment indicators by farmers. On fields treated with stone terraces, farmers pointed out that they noticed crop yield reduction year after year and between upper and lower terrace sections. They said that the lower was more productive than the upper terrace section. The choice of conservation measures was set depending upon the area occupied and amount of labor required. The points below, often listed as reasons for the failure of conservation measures (technological limitations), were some of the short term assessment indicators explained by farmers.

- High labor for construction and maintenance.
- Considerable area occupied by terraces.
- Narrow spacing for farming operations.
- Lack of construction materials.

While using these local indicators, farmers did not give necessary attention to ecological sustainability indicators. If a given conservation measure to be effective, it has to be measured in terms of both economic and ecological indicators.

5.7 Improvements on Soil Conservation Measures

The major focus of the participatory learning and action approach is to motivate and realize farmers' experiences and attitudes on the erosion processes, causes and impacts of soil erosion in order to increase the effectiveness of conservation measures. Once the farmers understood and analyzed the erosion problems at field and landscape units through local indicators and the limitations of existing conservation measures, they are asked to implement improvements that fit to their farming system and are affordable. These improvements are designed to solve wide terrace spacing and un-stabilized terrace cross sections, and minimize the identified causes and indicators of erosion like rill erosion, ditch erosion, gullies, and others. Terraces can be effective if and only if they are used in combination with other conservation measures. Through continuous field visits and on-site discussions land users can explore possible improvement options and new techniques. There are some successes recorded in improving the effectiveness of existing terraces in the case-study sites. More interestingly, some innovative farmers establish homestead demonstration plots for different soil fertility management measures which will help to motivate adjacent land holders. List of improvement options currently practiced by the farmers are described and illustrated below.

Trenches along terrace lines

Modified trenches (dimension is modified to fit to the plot slope and terrace conditions) are constructed to retain the runoff water and sediment from the terrace area (Fig. 26). It substitutes graded runoff storage basins or channels. The modified trench improves the terrace and gives multi-function:

- Retain the excess runoff water which otherwise overtops the terrace and cause damage to the structure and to down slope plots;
- Avoid sediment loss and off-site damage on side waterways and adjacent plots from excess drainage water from terrace channels;
- Retain sediment eroded from terrace area;
- Increase the amount of water goes to infiltration by reducing the overland runoff component;
- Increase available soil moisture during terminal drought and thus improves productivity of crops cultivated below the terrace structure;
- Increase the interflow and in the long term it might improve recharging;
- Use for compost preparation from weeds and other shrub species collected during cultivation period;

Fig. 26 Improved terrace structures using trenches

Value-added plantations

Free grazing is the challenge to promote multi-purpose tree plantation and biological conservation measures on terrace structures. Despite the grazing problem, in addition to local shrubs naturally grown along terrace structures, currently some farmers adapt some value-added plantations such as *tena adam* (Fig. 27) and grass pea and weeds for feed that fit into the annual cropping system, and *chibha* tree plantation.

Fig. 27 Improved terrace structures using high value spice plants

Improvements in the top terrace section

Damage to stone terraces due to instable cross sections is common. It is also difficult to maintain or improve stone terraces on steep slopes by adding more stones on top of it. Improvements are made on the top cross section of the terrace structure. The height of structures on the top side is limited up to the ground surface while the bottom riser height is increased to retain maximum sediments. This type of improvements increases structural stability and does not liable to mechanical damage. The inclined top cross section of the structure is developed through time by adding soil and local vegetation when the storage capacity is filled up by eroded sediments.

Fig. 28 Improvement on the cross section of terrace structures

Shifting terrace position

Shifting terraces upward or down ward within an interval of 4-5 years is common farmers' practice in the highlands. The farmers' reasoning to do this practice is that the deposited soil on the previous terrace structure is presumed to be fertile in comparison to the soil at a distant from the structure. And hence, crop yield increases when planting this part of land. However, limitations are observed after a certain period of years. This practice has caused disturbance of the already long deposited soil formed in the form of bench terrace and then the soil washed further down slope.

Fig. 29 Old terrace structures moved down slope

Check dam construction along water ways and gullies

Farmers have been constructing check dams on erosion risk waterways, foot paths and gullies. Farmers try to quantify sediments retained in the check dams every rainfall storms and during the whole season in order to increase their awareness about soil and nutrient loss from farm plots.

Fig. 30 Series of check dams constructed along path ways

Avoiding traditional ditches

Small trench like pits inside farm plots are discussed as options to substitute traditional ditches to control erosion upon lower section of plots and retain overland flow within the site. This minimizes soil loss by ditches and reduces the area lost by drainage ditches.

While improving existing soil conservation measures at field and landscape levels, some of the measures need careful collective decision and due emphasis during the implementation period.

i. **Improving old and completely sediment filled stone terraces on steep slopes**

- Raise questions like: if maintenance is carried out at the original position does it control erosion effectively? Is it not difficult to do continuous maintenance? When the stone terrace height is very high, it is liable to damage and the runoff overtopping the structure cause severe erosion at the bottom of the terrace structure.
- If the terrace structure is removed and shifted to the upward or down ward position, the accumulated sediments can easily wash away.
- Thus, it is very important to discuss the advantages and disadvantages of maintaining stone terraces on steep slopes to come up with effective solution

ii. **Constructing cutoff drains**

- Cutoff drains are only required when inflow runoff is very high, otherwise it results in severe damage when there is failure in the proper construction.
- It is always advisable to integrate and support the cutoff drain with biological measures.
- Cutoff drains are often the main source of conflict between farm owners in the topo-sequence. It is therefore essential to agree on the layout of drains with the presence of all concerned land owners.

iii. **Constructing new terrace structures**

- Terrace spacing is decided with the agreement of the land owner and it is in such away that rill formation and development is avoided.
- The upper and lower side height of terraces should not be necessarily equal on steep slopes in order to retain washed sediments due to sheet erosion and to increase structural stability.
- In order to increase the annual sediment storage capacity of terraces as well as to protect erosion damage to down slope area it is highly recommended for integrating physical structures with biological ones.

iv. **Constructing traditional ditches**

- The first and foremost advice regarding to traditional ditches is to protect the generation of concentrated runoff inside the field. If feasible replace with other in situ drain systems to control soil erosion within the field plots.
- Through past experiences on how the gradient affects runoff concentration and erosion in the ditch system, improve the gradient without causing damage.
- Care must be taken to avoid formation of gullies and terrace damage at the outlet of ditches.

v. **Promoting improved land management systems**

- As a result of continuous cultivation and erosion problems most of the marginal lands on steep slopes are degraded and unable to produce subsistence crop yields. It is better to change to other land use systems that benefit the farmer economically and bring sustainable natural resources.
- Since tillage frequency is one cause for accelerated erosion it is advisable to practice minimum tillage techniques and strip cropping, and cultivate crops which need less frequent tillage management.

Change in practices of farmers

Since the start of the research project farmers assessed erosion problems and accordingly planned suitable erosion control measures on individual plots through consensus. Apart from the usual and commonly available soil conservation measures in the area the above improvement options were practiced in the project period. During the first year, some of the improvement options such as trenches, plantation of high value plant species and modification of traditional ditches were only observed on innovative farmer plots which need further commitment and follow up to scale up at the landscape and catchment scales. In the first year, construction of trenches along the terraces was practiced only by one farmer, while this practice was scaled out to additional nine farmers in the second year with a total of about 557 trenches. Therefore, in order to ensure whether the farmers' accept and adopt their planning decisions to implement the improvement options, the change in practice were measured and quantified on individual farmer plots and communal areas at the end of the project period.

Table 7. Change in practices of the planned improvements during the end of the project period (April 2010)

Site	Terrace maintenance (m)	New terraces (m)	Cutoff drain construction (m)	Communal check dam (count)			Trenches (count)
				1st year	2nd year		
				New	Maintenance	New	
Chira Godguadit	2984	230	247	55	47	14	--
Chira Kiltimsebari	2868	376	97	85	109	--	557

6. Summary and Conclusion

Small holder farmers under the crop-livestock farming system usually manage their land plots for short-term maximization of benefits rather than with a longer-term perspective of sustainable land management. This means that they miss out on the longer-term benefits of environmental services. It is thus essential that farmers and local planners in land management develop greater awareness about the natural environments. In the highlands of Ethiopia, many soil conservation measures were implemented to tackle soil erosion and land degradation but are not fitted to the farming system and eventually less adopted by farmers. Less attention to local erosion assessment based conservation approaches and lack of assessment of aspects that represent farmers' perspective are often indicated reasons for the failure of soil conservation programs. Agricultural lands are exposed to soil erosion because it experiences frequent tillage before and during the start of the rainy season annually. Given such soil management practices rill formation is the predominant form of erosion which constitutes about 13-60 t ha^{-1} (or 60-170 m^3 ha^{-1}), and without effective control measures it developed into gullies and to severe land degradation. Therefore, there is a need for understanding the characteristics of local specific rill formation and its development on different sets of environmental and land management factors through interactive and participators approaches with farmers.

One important form of erosion assessment is from direct field measurement of erosion features consist of rills. Rills are simple to identify by farmers in order to use as an indicator to control erosion on their fields. It is in this smallest hydrological unit on the most upstream part of the river network system that erosion takes place that lead to degradation of upper catchments and siltation of water reservoirs. Thus erosion assessment at the scale of rill channels can be taken as the basis for the planning and design of erosion control strategies at any larger scale down the channel.

The low efficiency of stone terraces to control rill formation brings about 10 to 46 % biomass yield reduction on top terrace area compared to bottom position. There was a general pattern of rill erosion increase with slope length between terraces. Rill formation and rill development over the topo-sequence has revealed the local specificity of erosion. The presence of conservation terraces, drainage ditches, field boundaries, foot paths and waterways inside the catchment have also played great role for the longitudinal rill development either by dissipating runoff energy or as sources of concentrated runoff. These are detrimental factors for rill formation and development at individual field as well as landscape scales which clearly indicates the role of land users' intervention. Individual farmer's decision on the design and layout of terraces and land management practices in their own field determined the spatial rill formation and development within terrace area. An integrated effect of individual farmer's land management decision, and communal land use and sources of conflicts in the management of runoff water determined rill formation and development on topo-sequence of the landscape.

The methodology as well as the approach described here has provided positive impacts on the local knowledge and attitude of farmers such that it is widely explored and utilized, and to be integrated with technical solutions. In addition, the farmers have been empowered through the ownership of the erosion assessment, planning of conservation measures and implementing processes. Action plans developed by farmers through participatory learning and action become the means by which locally suitable and cost effective soil conservation measures are improved, promoted and widely adopted. It also brings an impact in generating innovative practices, minimizing sense of dependency, targeting on sustainable land management options, and understanding the importance of seasonal effects of tillage, sheet and rill erosion for long term land degradation.

The results of an interactive erosion evaluation and soil conservation planning exercise brought the common understanding by the involving farmers of what needs to be done by them, where, for what purpose and with what end in mind. This is in order that erosion problem issues can be tackled and overcome by themselves, when supported and motivated by experts. By focusing erosion assessment and evaluation at farmers level, improved soil conservation planning that match with the local capacity will be developed that have direct relevance and application to sustainable land management activities at grass roots level. In this way, it will be possible to establish farmers' team who are responsible to assess and evaluate local erosion and plan for its control.

In summary the main strength of the participatory erosion assessment and evaluation approach as well as rill erosion based assessment method by farmers is that it incorporates a grass roots level knowledge and experience, as opposed to the typical top-down design and planning. Eventually, this erosion assessment method using rill erosion indicator and local farmers' participatory approach can be adopted at wider scale by developing working guideline in order to strengthen and support the existing soil conservation extension service.

7. References

Bewket Weldeamlak, and Sterk, G., 2003. Assessment of soil erosion in cultivated fields using a survey methodology for rills in the Chemoga watershed, Ethiopia. Agriculture, Ecosystems and Environment 97: 81–93

Birru, Y., 2007. Land Degradation and options for sustainable land management in the Lake Tana Basin (LTB), Amhara Region, Ethiopia. PhD Thesis, Centre for Development (CDE), University of Bern.

Carucci, V., 2000. Guidelines on water harvesting and soil conservation for moisture deficit areas in Ethiopia: the productive use of water and soil. Manual for trainers' first draft. Addis Ababa, November 2000.

Gime´nez, R., and Govers, G., 2002. Flow Detachment by Concentrated Flow on Smooth and Irregular Beds. Soil Sci. Soc. Am. J. 66:1475-1483

Herwege, K., 1996. Field manual for: Assessment of current erosion damage. Soil Conservation Research Programme, Ethiopia and Centre for Development and Environment, University of Berne, Switzerland.

Herweg, K. and Lude, E., 1999. The performance of selected soil and water conservation measures- case studies from Ethiopia and Eritrea. Catena 36.

Herwege, K. and Stillhardt, B., 1999. The variability of soil erosion in the highlands of Ethiopia and Eirterea. Average and extreme erosion rates. SCRP, Research Report 42. University of Bern, Switzerland in Association with MOA, Ethiopia.

Hurni, H., 1984. Soil conservation research project Ethiopia, Vol. 4, Third progress report (1981), University Bern and United Nations University.

Hurni, H., 1986. Guidelines for development agents on soil conservation in Ethiopia. CFSCDD, MOA, Addis Ababa.

Kilewe, A. M., 1986. Measurement and Prediction of soil erosion in Kiambu and Muranga Districts of Kenya. National Environmental Secretariat Publication, Nairobi.

Lakew Desta, Carucci, V., Asrat Wendem-Agegnehu and Yitayew Abebe (eds), 2005. Community Based Participatory Watershed Development: A Guideline (Part 1 and Part 2) Ministry of Agriculture and Rural Development (MOARD), Addis Ababa, Ethiopia.

Million, A. 1996. Traditional ditches in North Shewa, Ethiopian highlands. In: Chris Reij, Ian Scoones and Camilla Toulmin (eds). Sustaining the soil: Indigenous soil and water conservation in Africa, London. Pp 156-162

Mitiku, H., Herweg, K., Stillhardt, B., 2006. Sustainable Land Management – A New Approach to Soil and Water Conservation in Ethiopia. Mekelle, Ethiopia: Land Resources Management and Environmental Protection Department, Mekelle University, Bern, Switzerland: CDE, University of Bern, NCCR North-south, 269 pp.

Moore, I.D. and Burch, G.J., 1986. Modelling erosion and deposition: topographic effects. Transactions of the ASAE 29: 1624-1640.

Nyssen J., Poesen, J., Mitiku H., Moeyersons, J. and Deckers, J., 2000. Tillage erosion on slopes with soil conservation structures in the Ethiopian highlands. Soil & Tillage Research 57: 115-127

Rejman, J. and Brodowski, R., 2005. Rill characteristics and sediment transport as a function of slope length during a storm event on loess soil. Earth Surf. Process. Landforms 30: 231-239.

Rieke-Zapp, D. H., and Nearing, M. A., 2005. Slope shape effects on erosion: A Laboratory Study. Soil Sci. Soc. Am. J. 69:1463-1471

Taffa, T., 2002. Soil and water conservation for sustainable agriculture. Mega Publishing Enterprise, CTA

Torri, D., Sfalanga, M., Chisci, G., 1987. Threshold conditions for incipient rilling. Catena Supplement 8: 97-115.

Yohannes, G. and Herweg, K., 2000. From indigenous knowledge to participatory technology development. Centre for Development and Environment (CDE), University of Bern

8. Annex

Table A.Field plot characteristics of rill survey fields at case-study catchments

Catchment	Field plots	Area (ha)	Slope (%)	Number of terraces	Average terrace spacing (m)	Total length (m)	Terrace x-section (m^2)	Slope position
Chira Godguadit	1	0.17	40.97	2	15.00	78.00	0.89	Upper
	2	0.21	31.41	3	14.50	147.00	0.53	Upper
	3	0.30	42.82	4	12.00	147.00	0.73	Upper
	4	0.50	37.75	3	17.20	131.00	0.27	Middle
	5	0.41	34.04	3	10.00	153.00	0.76	Middle
	6	0.06	42.95	2	5.00	47.00	0.59	Middle
	7	0.18	38.07	3	14.00	126.00	0.43	Lower
	8	0.67	36.92	2	17.00	165.40	0.42	Lower
	9	0.06	39.77	2	15.20	22.40	0.79	Lower
Chira Kiltimsebari	1	0.49	41.00	7	12.75	389.00	0.51	Upper
	2	0.26	35.00	3	7.00	169.00	0.54	Upper
	3	1.07	47.00	7	13.33	348.00	0.44	Middle
	4	0.80	49.00	8	12.83	407.00	0.41	Middle
	5	0.60	45.50	5	20.33	282.00	0.45	Middle
	6	0.28	52.00	1	18.00	35.00	0.35	Lower
	7	0.39	44.70	4	13.00	182.00	0.47	Lower
Arbaba Embestig	1	0.54	31.25	5	11.63	360.50	0.59	Upper
	2	0.54	32.13	3	14.15	222.10	0.54	Upper
	3	0.57	25.50	4	11.60	219.30	0.37	Middle
	4	0.10	28.20	2	18.20	51.60	0.42	Middle
	5	0.06	9.00	1	-	25.00	0.25	Lower
	6	0.34	11.80	1	-	59.50	0.44	Lower
	7	0.09	22.00	1	-	27.00	0.42	Lower

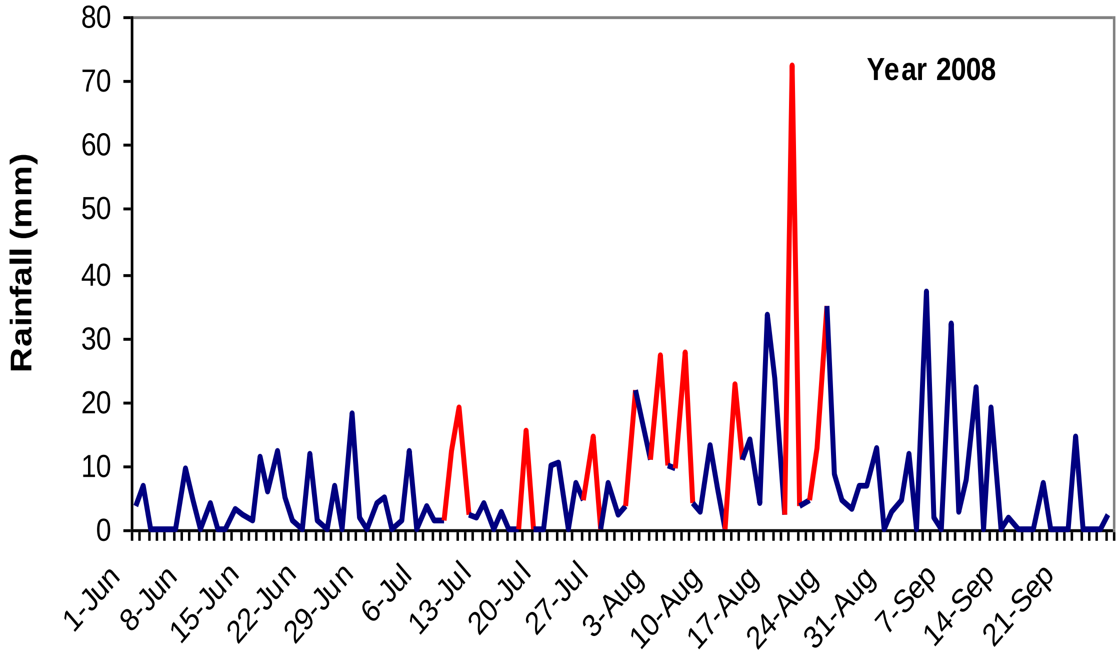

Figure A. Rainfall pattern at the study catchments during July-August 2008

Figure B. Terraced hillslope exposed with soil erosion hazard