PERFORMANCE EVALUATION AND CONSTRAINTS FOR ADOPTION OF SOIL AND WATER CONSERVATION MEASURES IN GOJAM HIGHLANDS, ETHIOPIA

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DECLARATION

hereby declare that this thesis is my original work and has not been presented for a degree in ny other University All sources of information have been acknowledged

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DEDICATION

This thesis is dedicated to my wife, Medhanit Yitna and my son Binyam Berhanu

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ABSTRACT

Data on rainfall, runoff, soil loss, crop yield and land use have been collected from Anjeni soil conservation research unit since 1984, in order to evaluate the performance of different soil and water conservation measures on runoff, soil loss and crop yield and based on these, to identify the most suitable soil conservation measure(s) for the study area and other areas having similar environmental conditions The experimental treatments evaluated were: grass strip, graded bund, graded fanya juu and traditional farming (control plot). The experiments were carried out on 6 m x 30-m plots located in two sites with different slope (28 % and 12 %). However, despite such an amount of input in terms of labour, time and money, this raw data had not been analyzed. The first part of this study aimed at analyzing this data in order to evaluate the performance of these treatments in minimizing soil loss and runoff The second part of the study assessed the opportunities and constraints for the adoption of soil and water conservation measures in Gojam Highlands

The result showed that the highest mean annual runoff (501.3 mm, 30.6% of the mean annual rainfall) and soil loss (122.1 t/ha) was measured on traditional farming (control plot) in experimental plot I (28% slope). The lowest mean annual runoff (275.3 mm, 16.8% of the mean annual rainfall) and soil loss (30.3 t/ha) in this plot was measured on the grass strip In experimental plot II (12% slope), the highest mean annual runoff (451.5 mm, 27.5% of the mean annual rainfall) and soil loss (88.2 t/ha) was measured on the traditional farming. The lowest mean annual runoff (263.6 mm, 16.1% of the mean annual rainfall) and soil loss (25.6 t/ha) in this experimental plot was measured on graded fanya juu However, no clear difference had been observed on crop yield between treatments at both sites Statistical analysis showed that all the soil conservation structures investigated except traditional farming (control plot) are effective in controlling soil erosion on the steeper landscapes (EP I), while at lower slope (EP II) only graded fanya juu was found to be effective in reducing runoff and soil loss when compared with the control plots.

A questionnaire survey was carried out in Gojam highlands, Ethiopia It covered four agro-climatic zones, namely Wurch, Dega, Weyna Dega and Kolla These zones are located at different altitude, topography and farming systems Ten households were interviewed at each agro-climatic zone The study revealed that most of the soil and water conservation work has been destroyed or modified by the farmers to suit local conditions at higher altitude (> 2300 m asl)

In Wurch zone, 30, 10 and 60% of the respondents indicated that the output (crop yield) of soil and water conservation measures was high, low and insignificant respectively In Dega zone, 50, 10 and 40% of the respondents indicated that the output of soil and water conservation measures was high, low, and insignificant respectively In Weyna Dega zone all the respondents said the output of soil and water conservation measure (traditional ditches) was high In Kolla zone, 90 and 10% of the respondents indicated that the output was high and insignificant respectively

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1 INTRODUCTION

1.1 Background

In Ethiopia 88% of the human population, 60% of the livestock, and 90% of the area which is suitable for agriculture is concentrated in the highlands which are more than 1500 m asl (Constable, 1985). Agriculture and livestock sectors are economically important to Ethiopia and they contribute to more than 90% of Gross National Product. A large portion of land is exposed to erosion and the precious topsoil has gone at an alarming rate. The data on soil loss rates collected by Soil Conservation Research Project (SCRP) up to 1986 range from 0 to 282 tons/ha/year, showing high variation in soil loss rate in the Ethiopian highlands which could be due to variation in topography, land use and climatic conditions (Mulegeta, 1988). The high soil loss rates on cultivated areas indicate the need for conservation measures to be applied to a wide range of ecological zones in Ethiopia. According to the work of Hurni (1993), an average soil loss of 42 t/ha/year from cropland will remove the total soil of the present cropland within 100-150 years. The resulting annual production loss due to soil loss is between 1 and 2%. This threatens the ability of Ethiopia to feed its growing population.

The Government of Ethiopia, in recognition of the severity of the problems associated with soil degradation, has initiated, with the support of international and bilateral agencies, a massive programme for afforestation and soil conservation. The World Food Programme (WFP) became involved in this sector of rural development in the mid-1970s and expanded its support continuously. Other agencies, such as the European community, FAO, and bilateral organizations, also contributed to these efforts. Altogether, soil conservation and afforestation reached a total estimated input level of US$ 40 million per year in 1985 (WFP, 1986), voluntary work not included.

The soil conservation research project was established in Anjeni in 1984. The main objectives of the Soil Conservation Research Project are "to provide the Ethiopian soil conservation effort with necessary basic data for the proper implementation of soil conservation measures, and to train locals as well as international personnel in this field of study" (SCRP 1981; SCRP, 1985) To this end, seven research station were set up in a wide range of agro-climate zones since 1981 and beside other activities, basic data on erosion processes were generated from test plots (Grunder, 1986) Hurni (1985), underlining the need for research to evaluate the performance of different soil conservation measures in different agro-climatic zone writes:

> *"... present day soil and sediment losses from slopes and in rivers amount to horrifying quantities ... conservation activities, including aiming at a better understanding of the situation, and a contribution to its improvement, belong to the heart of development efforts .."*

One of the research units is situated in the area of Anjeni, on the lower slopes of the central mountain systems of Gojam region In Anjeni, about one-square-kilometer catchment was chosen in 1984 for monitoring at catchment, household and plot level While climatic parameters, hydrologic processes, soil erosion and sediment loss are continuously quantified for each storm, other parameters like areas under different land use types and crop yields are quantified for each cropping season

1.2 Justification of the study

The government of Ethiopia in collaboration with NGO's launched a massive soil conservation programme in the 1970's to arrest and reverse the process of soil degradation In order to effectively implement the programme, huge sums of money were pumped into the programme and a substantial portion of the peasant labor force was mobilized. By the mid of the 1980's, the programme expenditure had reached around 50 million dollars per year and around 30 million peasant work-days were mobilized per annum to carry out the programme (Solomon, 1994). The reports indicate that between 1975 and 1989, around 980,000 ha of crop land were treated with various types of terraces; 310,000 ha of degraded grazing land were closed for natural regeneration; 296,000 ha of highly denuded land were re-vegetated; and 208,000 ha of hill side terraces were constructed (National Conservation Strategy, 1990).

> Timberlake (1984), witnesses this: *"I saw these terraces all along the road side on the main north-south road through Wollo Region, and found them as impressive a product of human physical labour as Egypt's pyramids. Paul Valley of The Times of London described a seemingly endless network of ditches cut into the sides of hills. It is as if contour lines were the invention of the farmer rather than of the cartographer. It is the result of one of the most massive anti-erosion programmes undertaken anywhere in Africa".*

However, most of the resent reports are rather discouraging and the results have not been what could have been expected, in light of the expenditures. Why has the success rate of such efforts been so poor in the Ethiopian highlands, when such efforts have been successful in other parts of the world and even in many parts of Africa (for example, in Machakos district, Kenya [Timberlake, 1984])? Poverty or poor farming system or topography or erosive rainfall or a combination of these environmental impact is usually mentioned as the major factor contributing to its failure and on this line different reasons were given on the unsuccessful story of soil conservation programme in the Ethiopian highlands. Hurni (1985) recognized that problems arise due to uniform application of single measures to the different agro-climatic condition. Grunder (1986) also consider this fact as the main reason why the conservation effort in the country has resulted in a much lower impact than expected.

The success of the programme was constrained by promotion of inappropriate technologies. Uniform applications of a single measure for different agro-climatic zones are neither appreciated nor adequately maintained by the beneficiaries. Instead of conserving land, poorly maintained structures may subsequently lead to increased down slope erosion by concentrating runoff through overtopping or terrace failure. When this occurs, the sudden release of the water pounded up on the hillside can do more damage than if no terraces had been constructed. Research directed to the development of conservation measures that are suitable for the different agro-climatic zones of Ethiopia has, therefore, become a very pressing task and an important aspect of the overall conservation movement in the country at the moment.

To support the effort of soil and water conservation activities, by providing scientific information, the soil conservation research project was initiated and consequently established at different agro-climatic zones. However, despite such an amount of input in terms of labor, time and money, the raw data that has been collected for the last eight years has not been analyzed. This study aimed at analyzing this data in order to evaluate the performance of these treatments in minimizing soil loss and runoff. A complementary field study aimed at assessing the level of adoption of soil and water conservation measures, opportunities and constraints would add value to the existing data and provide information upon which decision of technologies and approaches to be used to promote adoption to be based.

1.3 Study objective

The overall objective of the study was to evaluate the performance and assess constraints and opportunities of adoption of soil and water conservation measures.

The specific objectives were:

1. To evaluate the effectiveness of different soil conservation measures in terms of runoff loss, soil loss and crop yield using data collected in Anjeni Research Unit between 1984 and 1992
2. To undertake field survey to assess the level of adoption of conservation technologies in Gojam Highlands and the potential and constraints for widespread adoption.

2 LITERATURE REVIEW

2.1 Global problems of soil erosion

Most semi-arid regions suffer severe erosion, often more than in the humid tropics, because the rain has a high erosive capacity which is more damaging as a result of reduced vegetative covers. A recent survey showed that 40, 50 and 67% of the area in Morocco, Turkey and Greece were suffering moderate to severe erosion damage respectively (Hudson, 1987). Equally alarming rainfall erosion problem are reported in parts of the USA, Mexico, north-east corner of Brazil, and much of south-east of south America, the Sahel and the South-west of Africa (e.g. Botswana), overstretching east from Africa through Turkey, Iraq, Iran, and Afghanistan, with one arm extending into eastern USSR and China, and the other arm South of the Himalayan through Pakistan to India. In Australia, most of the states have severe rainfall erosion problems even in the area of low rainfall.

Lal (1977) states that vast areas of the highlands in Ecuador, Colombia and other area of the Andes have been either destroyed or seriously damaged by erosion. FAO (1983) also indicates that 13% of the crop land of Argentina, 27% of the total area of India and 11.6% of the total area in Africa north of the equator is affected by water erosion. Soil erosion is a serious problem particularly in the developing countries due to " a complexity of human and physical factors which undermine not only development projects but present day subsistence" (Stocking, 1981).

2.2 Soil erosion in Ethiopia

Some observers have indicated that degraded environments are the primary physical causes to the spread of deserts (United Nation, 1977) and famine (Cross, 1983). Hurni (1985), for example, states that the high soil loss rates in Ethiopia are "basic elements in understanding the recurring famines". Of the complex environmental problems Ethiopia faces today, soil erosion and deforestation remain the most serious. Both are already widespread and continue to spread further. Some 270,000 km^2 is thought to be eroded significantly and about 20,000 km^2 of farm land deemed to be undermined of their fertility and productive base (Highland Reclamation Study, 1986).

Soil erosion in Ethiopia has seriously damaged national economy and gravely affected the well being of more than 85% of the rural population. Most of the erosion processes are due to inappropriate land use, poor land management, steep slopes, fragile soils, and increased pressure on both arable and grazing land on top of these practices of primitive/unimproved traditional farming systems. Forests and marginal lands are often used for cultivation and fallow periods are shortened due to high population pressure and this accelerates erosion.

The scale of the problem may be subject for debate, but there is no doubt that soil erosion is one of the most serious threats of food production over most parts of the country. In extreme cases land has been so badly degraded that it is abandoned by farmers, but it is the gradual degradation of soil fertility that menaces farmers throughout the country which is more sinister and wide spread.

The Highland Reclamation Study (1986) further predict that "even if erosion rates stay at their current levels, it is projected that land covered by soil less than 10 cm deep (and thus incapable of sustaining crops) will increase five-fold to about 100,000 km^2 or some 18 percent of the Highlands area by the year 2010". Therefore, by the year 2010, 100,000 km^2 of arable land will have lost a considerable proportion of nutrients, its organic mater, and its water holding capacity and rooting anchorage.

According to the work of Harrison (1996), no country in Africa needed an effective conservation programme more urgently than Ethiopia. The pressure of population has forced farmers to cultivate on steeper slopes. The document further pointed out that, more than half of the Highland areas show signs of accelerated erosion. Each year it is estimated that 3.5 billion tonnes of topsoil are washed away, an average of 70 and 100 t ha^{-1} from cultivated land. Indeed annual losses of almost 300 t ha^{-1} have been recorded in the case of sloping fields ploughed to a fine tilth for the tiny-seeded traditional cereal, teff. The same document indicated that in 1900, Ethiopia's forests stretched over 48 million hectares. Today they are down to 4.7 million-an average annual losses of half a million hectares. As a result, rain no longer infiltrates and a lot of it is lost as surface runoff.

The study by Soil Conservation Research Project (SCRP), however, has estimated soil loss rates (on cultivated land) of up to more than 200 tons/ha/year from test plot results. Estimates of soil erosion rates from various land use types are also given by Hurni (1986) in which the erosion rate from all types of land uses for the highlands is estimated at 1.5 billion tons per year. Nearly half of these (672,000,000 tones) are from cropland that constitutes only 13.1 % of the total area of the country. On the other hand, estimated soil formation rates for cultivated land range from 5 to 11 tons/ha/year (Hurni, 1986). The two differing rates show the accelerated nature of the erosion process existing in the highlands.

Similarly the Highlands Reclamation Study (HRS) estimated that between 1985 and 2010, the rate of land degradation will cost 6500 million USD. Of this cost, 78% is due to losses in the cropping areas. Overall, 25% of the highlands are seriously eroded. Already 4% of the total Highlands are so seriously eroded that they will not be economically productive again in the foreseeable future.

According to Hurni (1993), current soil loss rates are highest from cultivated land (42 t/ha/year), where more than half of all field losses occur. Other land use types produce only half as much total soil loss, although their Arial extent is up to four times larger.

2.3 Soil erosion and conservation research

Plaisance and Cailleux (1981) listed classifications of erosion based on mode of action as chemical, running water, *en masse* movement, wind and biological. All these have been involved in geological erosion (as opposed to accelerated erosion caused by man), which has resulted in wearing down of mountains, cutting of canyons and wearing away of landscapes.

Many and probably all of the world's agricultural areas have resulted from geological erosion

Accelerated soil erosion research originated in United States in the 1920's. Since then, much knowledge about the causes of soil erosion and, for some areas and regions about its magnitude, extent, measures of control and its effect on soil productivity have been acquired. Belpomme (1977) observes that in the 1970's alone, over 10,000 studies on soil erosion phenomena have been published throughout the world. Most of these research outputs are concentrated in the United States, Europe and in a few other countries with active research centers, whereas there is a scarcity of research in large areas of the world (Hudson, 1981, Stocking and Peaks, 1985).

In general, three major themes of research on soil erosion can be identified (1) assessment of potential and actual erosion damages by direct surveys; (2) identification of the factors that cause soil erosion, assessing their relative strength in causing soil erosion and developing models for estimating soil losses and (3) investigation of the effect of soil erosion on soil productivity

Assessment of potential and actual erosion damages has involved the use of qualitative descriptions, small scale maps, questionnaires, aerial photographs and nowadays remote sensing techniques (Mulugeta, 1988). According to Herweg (1990), rill mapping has been used as the basic way to get spatially differentiated information about erosion damage, supplemented by various groups of sediment troughs to consider the amount of soil washed into the rills from the adjacent small catchment. De Boodt and Garbles (1977) reported that erosion is a hazard in many countries of Europe including Britain, Belgium and Germany and in the United States. However, as indicated by Blaikie (1985), the impact of soil erosion on agricultural production in these countries is concealed by adding more fertilizers

Identification of the major variables that determine the rate of soil erosion and developing quantitative methods for estimating (predicting) soil losses has been receiving the attention of several researchers particularly since the 1950's. A group of US Scientists used laboratory and field experiments to test and formulate each of the major factors that cause soil erosion and the result of several years of research endeavour is the evolution of the universal soil loss equation (USLE) in the 1950's (Morgan, 1986). The first attempt to develop a soil loss equation for hill slopes was that of Zingg (1940) who related erosion to slope steepness and slope length. Further developments led to the addition of a climatic factor based on the maximum 30 - min rainfall total of a two year return period (Musgrave, 1947), a crop factor to take account of the protection effectiveness of different crops (Smith, 1958), conservation factor and a soil erodibility factor. Changing the climatic factor to the rainfall erosivity index (R) ultimately yielded the universal soil-loss equation (Morgan, 1986)

$$A = R\ K\ LS\ C\ P$$

Where. A = mean annual soil loss ($t\ ha^{-1}\ yr^{-1}$)

R = the rainfall erosivity index which is equal to the mean annual erosivity value divided by 100

K = the soil erodibility index defined as mean annual soil loss per unit of erosivity for a standard condition of bare soil, no conservation practice, 5^0 slope of 22 m length

LS = the factors of slope length (L) and slope steepness (S) are combined in a single index (L is in meter and S in percent)

C = the crop factor which represents the ratio of soil loss under a given crop to that from bare soil

P = the conservation practice factor

The problems associated with soil erosion and land degradation, which have caused widespread famine in developing countries, have long prompted interest in soil conservation research. The world soil conservation research has been geared toward the development of three complementary erosion control measures (Mulegeta, 1988), namely: (1) Agronomic (biological) measures which aim to reduce soil erosion through the improvement of soil vegetation cover, (2) soil management measures are concerned with influencing the erodibility of the soil by improving its structure (and hence its infiltration capacity) so that it is more resistant to erosion and (3) mechanical methods that seek to develop measures which involve earth moving and soil shaping practices for reducing the velocity of runoff. These measures are therefore complementary

Hudson (1981) setup experiments in Zimbabwe to investigate the effect of cover on soil loss The result of his nine years experiments showed that the mean annual soil loss and runoff from a tilled, continuously weeded plot was 127 and 13 times more, respectively, than from a continuously weeded plot having the same soil type and slope gradient but covered with wire grid of appropriate gauge to simulate a full vegetative cover.

Quoting from the research done by Lal in Nigeria, Greenland and Lal (1977) also indicated that the runoff from the bare fallow plots was 16 times more than that from the plots treated with 6-tons/ha mulch Marston and Perrens (1981) compared the effect of zero-tillage and stubble incorporation to tillage on runoff using simulated rain in the northern wheat belt of Australia. They found out that the zero-tillage and retention of crop residue significantly reduced runoff velocity and therefore soils loss

Sheng (1981) studied the effects of two types of structures, bench terraces and intermittent terrace (terraces in which every third bench is actually constructed, the intermediate land being untreated) All structures reduced soil loss by about half-compared to the control plot, but no significant difference in soil loss was found between the structures

2.4 Soil erosion and soil conservation research in Ethiopia

Apart from soil erosion surveys and evaluations and some isolated studies in various parts of Ethiopia, no consistent research activity existed until 1980 (Hurni, 1986) Most of the soil erosion and conservation research in Ethiopia is undertaken through the Swiss funded SCRP (Mesfin, 1991) Gunner (1969) gives a brief qualitative treatment of the process of soil erosion and relates this to actual situation in Chilalo Awraja. Other cases of soil erosion study in Ethiopia include El-Hassanin (1985) who studied the problem of soil erosion on the Awash valley while Asefa (1986) assessed the degree and extent of soil erosion using MSS Landsat method of data interpretation His study recognizes six soil erosion severity classes (1 to 6) in Ethiopia, with rating 1 denoting least severity and 6 highest severity

Hurni (1993) reported that soil loss rates from test plots in the Ethiopian Highlands ranged from 0 to 400 t/ha/yr, with average values of 42 t/ha/yr for cropland, 5 t/ha/yr from grassland, and 70 t/ha/yr, for bad land (a term applied to degraded land in the highlands). Similarly, he showed that sediment losses from small watersheds ranged from 0 to over 60 t/ha/yr (Table 1).

Table 1 Estimated rates of soil loss from different land use types in Ethiopia

Land cover type	Area (%)	Estimated Soil loss	
		t/ha/yr	Mt/yr
Cropland	13.1	42	672
Perennial crops	1.7	8	17
Grazing and browsing land	51.0	5	312
Totally degraded	3.8	70	325
Currently uncultivable	18.7	5	114
Forest	3.6	1	4
Wood and bush land	8.1	5	49
Total country	100.0	12	1493

Source: Hurni, 1993; (Mt = Million tons)

The finding and the historical evidence (Butzer, 1981) suggest that the great quantities of soil that have been removed from cultivated areas in the Ethiopian highlands for thousands of years and the high soil loss rates from slopes in the highlands have been accompanied by erosion-induced crop production declines and continuously depressed yields. A reduction of barley yield of 25 kg/ha for 1cm of soil loss on a Humic Andosol was measured in the Debre Birhan area in North Shewa (Hurni, 1985).

2.5 Soil and water conservation in the Ethiopian Highlands

Considering the rate at which soil conservation implementation has been undertaken in Ethiopia for the last 25 years, it is estimated that it would take another 70 years until all land in need of soil conservation measures has been conserved. Thus, the activities will have to be intensified many times in the future in order to attain stable conditions within the next 20 to 50 years (Hurni, 1986).

Table 2 presents a summary of three years of the implementation activities undertaken in the Ethiopian highlands in the period 1882 to 1985 (Hurni, 1986).

Table 2 Achievements of soil conservation activities in Ethiopia, from 1982 to 1985

Activities	Unit	FFW achievement[1]	Voluntary achievement[2]	Total achievement
Hillside terracing	km	203,085	29,744	232,829
Checkdam construction	km	1,662	1,057	2,718
Pitting and replanting	1,000pl	169,671	71,166	240,837
Seedling planting	1,000pl	148,590	91,180	239,770
Soil bund construction	km	95,175	44,400	139,575
Stone bund construction	km	79,860	46,626	126,486
Pond construction	no.	104	292	396
Dam construction	no.	11	40	51
Spring development	no.	205	2,221	2,426

1. FFW = Food for work. One workday compensated by 3 kg of grain and 120 gm of vegetable oil
2. Voluntary = Work organized through peasant associations in so-called *Zemechas* or days of compulsory group work.
pl = plants

The same document indicated that between 1976 and 1985, conservation and afforestation undertaken by the Ethiopian peasants, organized by the government and supported by external aid, amounted to some 600,000 km of soil and stone bunds on cultivated land, about 470,000 km of hillside terraces for afforestation of steep slopes, thousands of checkdams constructed in gullies, thousands of kilometers of rural roads, almost 80,000 hectares of closed areas for natural regeneration and many other land rehabilitation activities. Five hundred million tree seedlings were raised and planted, although the survival rates remained relatively low at around 20 percent.

Traditional conservation measures are well known in large parts of Ethiopia. For example, the people of Konso in Gamo Gofa region applied terracing on their cultivated land long ago (Kruger, et al, 1995). Some terraces can also be seen in the North regions and in low land areas where water conservation is necessary. Other areas like Gojam region have developed systems of ditches to drain surplus runoff.

Major soil and water conservation measures practiced in the Ethiopian Highlands are given in tables 3, 4 and 5.

Table 3 Physical soil and water conservation measures

Techniques	Description of the techniques
Bench terrace	Slope is converted into a series of steps, with a horizontal cultivated area on the step and steep rises between two steps
Checkdam	An obstruction wall across the bottom of a gully or a small river, which reduces the velocity of the runoff and prevents the deepening or widening of the gully
Contour ploughing	Ploughing along the contour and hence intercept the flow of run-on. Contour ploughing can keep more water in place and increase infiltration
Cutoff drain	A channel used to collect runoff from the land above and to direct it safely to water way or a river thus protecting the land below from excessive erosion. Cutoff drain usually protect cultivated land from up slope forest land or grassland
Hillside terrace	A structure along the contour, where a strip of land is leveled for tree planting
Level bund	Like graded bund except that it is constructed along the contour
Level fanya juu	Like graded fanya juu except that it is constructed along the contour
Micro-basin	A small structure with the shape of a half or a full circle, excavated to obtain a small basin for planting a tree. Micro-basins have sizes according to their design to conserve water, being small in moist and large in dry agro-climatic zones
Rough ploughing	The soil is purposely ploughed very rough to increase infiltration rate and to keep more water in place
Water way	A natural or artificial drainage channel along the steepest slope or in the valley and used to accommodate runoff

Source: Ministry of Agriculture (1986)

Table 4 Agronomic or biological soil and water conservation measures

Techniques	Description of the techniques
Agroforestry	Land use systems in which woody perennials (trees, shrubs, etc.) are grown in association with crops and/or livestock in a spatial or temporal arrangement in order to increase soil fertility
Alley cropping	An Agroforestry system in which food crops is grown in alleys between rows of hedges. The hedges consist of trees and shrubs such as leucaena or pigeon peas
Area closure	A protection system to improve land with degraded vegetation and/or through natural regeneration. No livestock is allowed to graze, and no human interference until an 80% natural grass cover is obtained
Cut and carry	A system of utilizing forages for stall-feeding. It can be applied in area closure in forest on conservation structures and in all areas where livestock is excluded for grazing
Grassland Improvement	Includes all activities aimed at improving the productivity of grassland whereby runoff and soil erosion is reduced. Activity includes the introduction of better forage species, moisture conservation, removal of unpalatable species, the cutting of shrubs, regular weeding and maintenance of soil fertility
Live fence	Planting of plant species around homestead along farm boundaries and along permanent drainage ditches. They are used to stabilize the embankment of drainage ditches and to avoid physical damage by human and uncontrolled livestock
Revegetation	A systems of forage establishment on land with a low vegetation cover. Such land can be newly constructed bunds, cutoff drains, waterways or degraded land and gullies
Strip cropping	Planting the same or different crops at the same time or in different time in rows. The strip crops can reduce both runoff and run-on and give sufficient ground cover during erosive rainy season
Stubble mulch	Stands of considerable amount of crop residues are purposely left on the surface after the harvest. The system prevents the rainfall impact, improve the fertility status of the soil and infiltration rate and in the final analysis reduces soil erosion
Trash line	Maize and sorghum straw layout as a grid system for the purpose of water harvesting, infiltration, soil trapping, interrupting runoff, minimizing splash effect and improving soil fertility
Tree planting	An activity to improve the vegetation cover of the ground, thereby reducing runoff and soil erosion and production wood. Tree planting supports many other conservation activities if combined with them

Source: Ministry of Agriculture (1986)

Table 5 Soil and water conservation measures experimented in Anjeni research unit

Techniques	Description of the techniques
Graded bund	A graded bund is an embankment with a gradient of up to 1 % towards a waterway or river, made of soil and/or stones, with a basin at its upper side. The bund reduces or stops the velocity of over land flow and consequently soil erosion. The bunds are about 50-75 cm high and have a bottom width of 100-150 cm. Such gradient is for surplus runoff to be drained if the retention of the bund is not sufficient. Tied ridges with top heights lower than the bund height serve to retard such flow and to provide small basins for water storage.
Graded Fanya Juu	A graded fanya juu ("throw up hills" in Swahili language) is an embankment made of stones and/or soil, with 1% gradient towards the waterway. The fanya juu reduces or stops the velocity of overland flow and consequently soil erosion. Unlike the graded bund, the soil in a fanya juu is moved upslope during construction. The water retention basin is thus at the lower side of the wall. The gradient is for surplus runoff to be drained if the retention of the fanya juu is not sufficient. Tied ridges behind the embankment provide small basins for water storage and guide the water over the bund into the ditch below from where it is drained sideways.
Grass strip	A grass strip is a ribbon-like band of grass laid out on cultivated land along the contour. Usually, grass strips are about 1 meter wide and spaced at 1 meter vertical interval. They are mainly used to replace physical structures on gentle slopes and on soils with good infiltration (sandy, silty).
Traditional ditches	Traditional ditches are constructed during each ploughing season and run diagonally across the slope of the cultivated land. They are made by pressing a Maresha plough deep into the ground and can be easily differentiated from the normal plough furrows. The gradient, spacing, number, length, width and depth of the traditional ditches are depends on the slope of the field, amount of rainfall (runoff and run-on), crop type and distance from waterways.

Source: Ministry of Agriculture (1986)

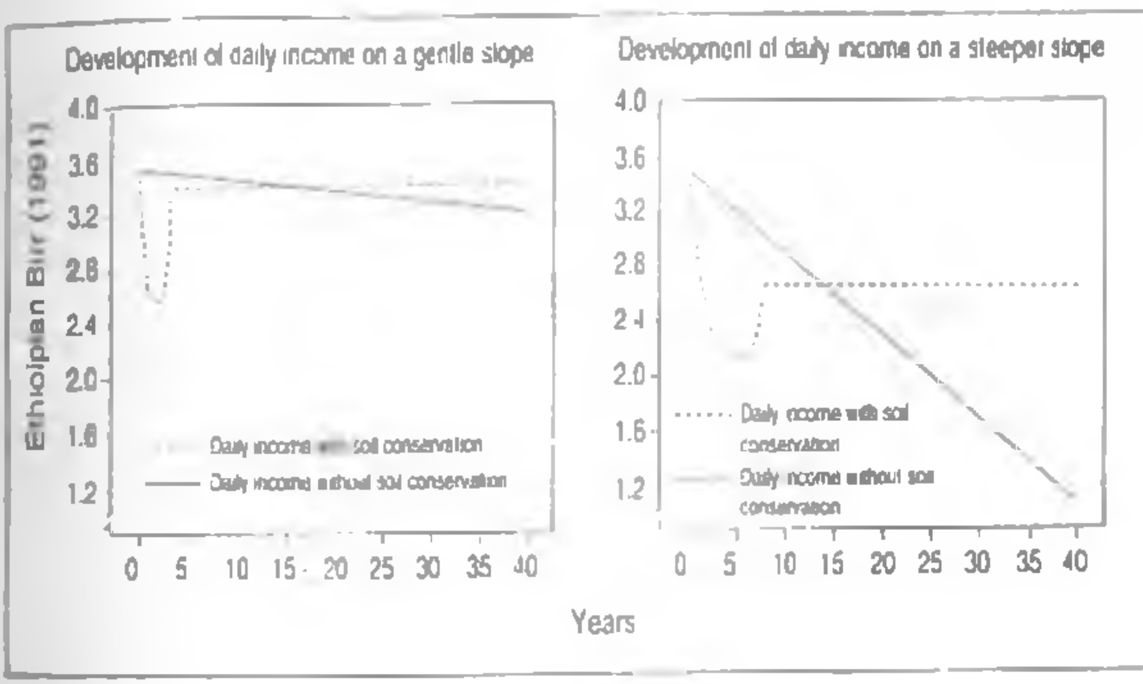
Table 6 Plant species suitable for soil and water conservation in different agro-climatic zones in Ethiopia

ACZ	Grasses	Legumes	Trees
Wurch above 3200 m asl	*Festuca, Danthonia, Poa*	*Trifolium*	*Erica, Hypericum, Hagenia, Cupressus, Some Eucalyptus, Juniperus, Schinus*
Dega (2300 - 3200 m asl)	*Andropogon, Pennisetum, Snowdenia, Vulpia*	*Trifolium and other local species*	*Juniperus, Olea, Nuxia, Maytenus, Euphorbia, Pygeum, Croton, Apodytes, Erythrina, Hagenia*
Weyna Dega (1500 - 2300 m asl)	*Hypericum, Themeda, Panicum, Harpachne, Pennisetum, Rhhodes, Cenchrus, Panicum, Phalaris, Setaria, Columbus*	*Trifolium, Lablab, Stylosanthes, Pigeon pea, Leucaena, Sesbania, Desmodium, Siratro*	*Juniperus, Olea, Euphorbia, Pygeum, Croton, Apodytes, Erythrina, Hagenia, Podocarpus, Ficus, Albizzia, Ekebergia, Adhatoda, Euphorbia, Prosopis, Acacia, Balanites, Casuarina, Schinus*
Kolla (500 - 1500 m asl)	*Cenchrus, Chloris, Panicum, Napier, Phalaris, Setaria, Columbus*	*Lablab, Stylosanthes, Sesbania, Macroptilium, Atriplex*	*Acacia, Moringa, Ailanthus, Parkinsonia, Schinus, Balanites, Albizzia, some Ficus, Casuarina, Tamarix, Ziziphus, Azadirachta*

Source: Ministry of Agriculture (1986).

2.6 Effect of soil and water conservation in the Ethiopian highlands

Most of the reports indicated that output from soil and water conservation structures are not immediate. It was revealing to observe that on a steep slope, soil conservation will pay only after a period of 30 years, way beyond the planning perspective of both the farmers as well as the government administration (Ludi, 1991). Even if investments are provided from external sources, the period needed for soil conservation to make financial returns is about 15 years (the crossing of the lines, Figure 1) On a gentle slope, results are more positives due to reduced erosion and less investment are needed From these studies it become clear that soil conservation is too expensive even at moderate investment level, and that more productive packages have to be found to attract the attention and interest of the farmers to embark on a sustainable soil utilization technologies (Hurni, 1994)



Source: Hans Hurni, 1994

Figure 1 Average daily income of an Ethiopian farming family with or without fanya juu on gentle and steep slopes

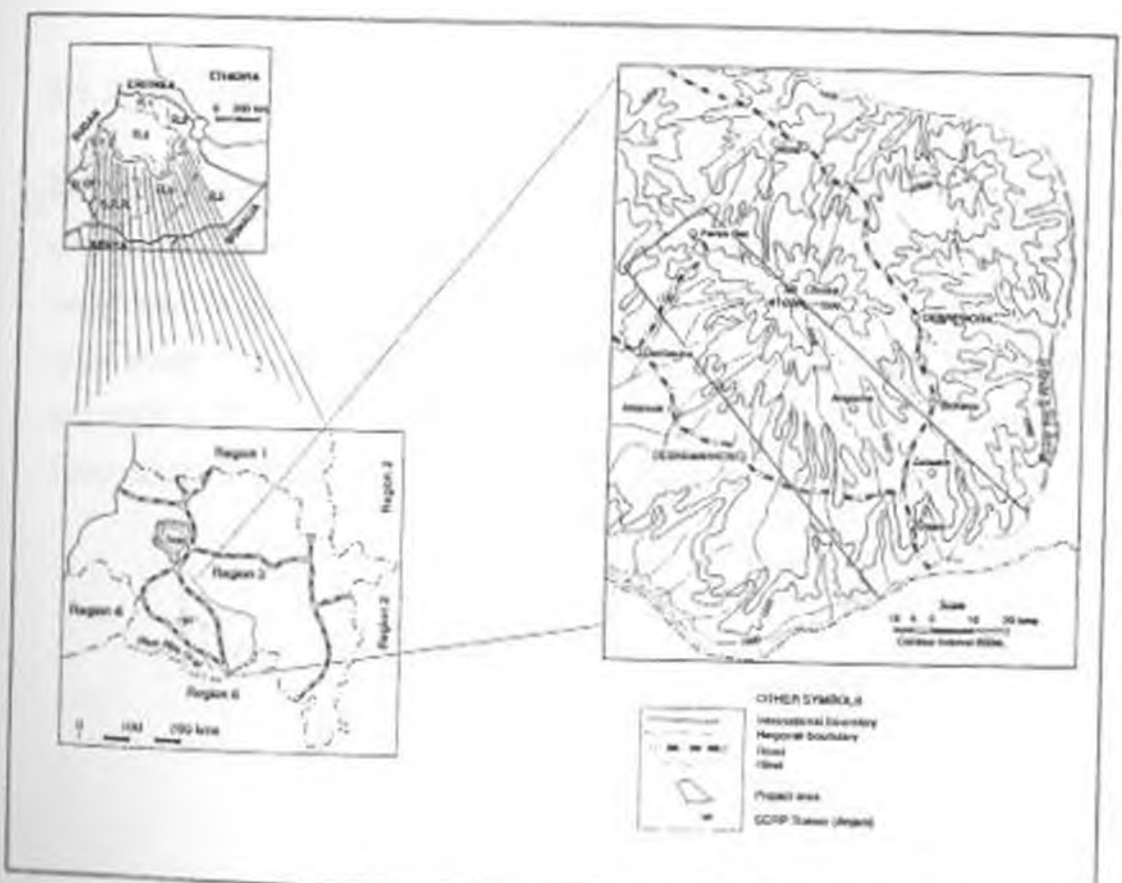
Studies in Kenya (Harrison, 1996) showed that terraced land pay-off are rapid and handsome The studies have shown that maize and bean yields of farmers with conservation measures are 60-100 and 80-130 percent higher than of those with none respectively The reasons for higher return and sustainable use of soil and water conservation in Kenya as given by Wenner (1981), are that soil and water conservation began by asking farmers about their problems, needs, and existing methods in use, and working with farmers in a series of regional projects to improve and perfect them. The end result was a set of measures that farmers could and would carryout themselves, with their own resources and limited expert help

3 MATERIALS AND METHODS

3.1 General description of the study area

3.1.1 Location of the study area

A cross-sectional assessment on the opportunities and constraints for the adoption of soil and water conservation was made across different agro-climatic zones of Gojam highlands. The cross-sectional area is part of the Blue Nile Basin. The area is situated in Gojam administrative zone in region 3. The Blue Nile River in the south east and Choke Mountain in the north west (Figure 2) border it.



Source: Ethiopian Mapping Agency, Addis Ababa, Ethiopia, 1978

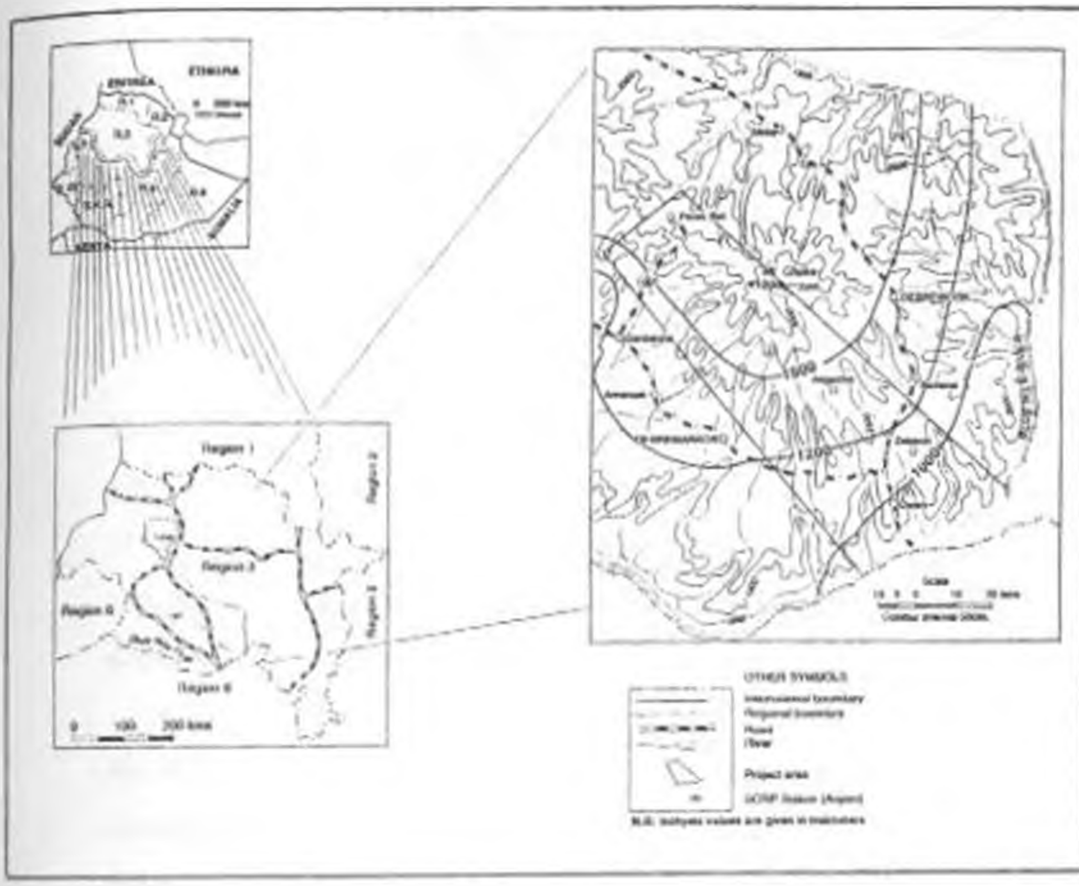
Figure 2 Location of the study area

The Anjeni Research unit is located in Gojam administrative zone Dembecha Woreda. The unit is about 365 kms north-west of Addis Ababa. The research unit was built in the Minchit catchment in 1984, at the foot of Choke Mountain on the road to Feres Bet at about 15 km of the Dembecha town. It is located latitude 10° 15′ N and longitude 36° 45′ E. The area is about 100 hectares.

The altitude of the research catchment ranges from 2170 to 2430 m asl. According to the soil conservation research project agro-climatic zonation system, its climate is categorized in the Dega belt. The research unit is typical of areas with unimodal rainfall in the north-western highlands of Ethiopia.

3.1.2 Climate of the study area

In the study area there is only one rainy season, 'Kremt", between May and September when more than 90 % of the total rainfall occurs. The temperature and precipitation of the study area is taken from the thermal zone map and mean annual map of Ethiopia respectively. The average annual air temperature for Blue Nile gorges and Choke mountain is 25 and 7°C respectively. The average annual rainfall varies from less than 1000 mm in the Blue Nile gorge to over 1500 mm in the Choke mountain (Figure 3).



Source. Land use planning project, FAO/UNDP - ETH/78/003, 1982

Figure 3 Mean annual rainfall pattern in the Gojam Highlands

The annual rainfall in Anjeni research unit was about 1610 mm based on the recordings of 1984 - 1992 at Anjeni research unit. Average annual rainfall for the area based on long period record is 1500 mm (Figure 3), which are about 7 % lower than the eight years record. In Anjeni research unit the lowest daily air and soil temperatures recorded are as low as 0 and -5°C and the highest as high as 33 and 40°C respectively. March is the warmest month with mean monthly minimum air and soil surface temperatures of 9.5 and 8.1°C and maximum of 26.1 and 32°C. August is the coldest month and has a mean monthly minimum air and soil surface temperatures of 10.4 and 10.7°C and maximum of 19.4 and 23.2°C respectively. Mean annual minimum and maximum air temperature in the Anjeni area is 9 and 23.3°C respectively.

3.1.3 Geology and geomorphology of the study area

According to the geological map of Ethiopia (Kefeni, 1995), central Ethiopia belongs geologically to the trap series of the Tertiary volcanic eruptions The geology of the study area consists of the Precambrian basement complex covered by Mesozoic sediments on top of which lies the trap basalt series

Most of the Dega and Wurch zones have rolling to hilly forms of land (8 to 35 % slope), while lower Dega and upper Weyna Dega have undulating to rolling land topography (2 to 15 % slope). The Weyna Dega zone (between Dembecha and Dejen) is almost flat to undulating (0 to 5% slope) The undulating land forms extend to the Gorge (0 to 60% slope) which has sharp and steep escarpment at the top of the gorge.

According to the work of Kefeni (1995), the Anjeni research unit lies over Precambrian crystalline bedrock which consists of granite and gene.is The bedrock is covered by deposit of Mesozoic sedimentary rocks, which is underlain by tertiary basalt and tuffs of the trap series that include rhyolites, which are responsible for the development of the easily visible flatter terraces and steeper slopes

3.1.4 Soils of the study area

According to the work of Kefeni (1995) and Venema and Paris (1986), the main soils occurring between Choke mountain and Blue Nile gorge are andosols, cambisols, gleysols, fluvisols, lithosols, luvisols, nitosols phaeozems, regosols and vertisols. Andosols occupy the convex and the top-most slopes of the mountains in the upper Dega zone Cambisols are associated with young parent materials or with steep eroded slopes in Dega and Kolla climatic zones They are found under moderately cultivated fields and natural vegetation covers. The fluvisols occupy the sloping valley sides and valley bottoms in the Dega and Weynadega climatic zones They were mainly found under grass covers and intensively and moderately cultivated fields. Nitisols are found in the gentle and moderately steep slopes in the Dega climate zone, which is associated with the plateaux. They are found under intensively and moderately cultivated cereals, pulses and oil crops. Luvisols are associated with gently to moderately steep slopes, which have been subjected to soil erosion in the Dega and Kolla climatic zones They are found under moderately cultivated fields Vertisols occur in flat to gently undulating plains on the plateaux in the *Dega* and Weynadega zones and are intensively cultivated Regosols occur on the sides of the high relief and on eroded slopes in the Weynadega and Kolla climatic zones They are mainly covered with natural vegetation.

In Anjeni areas the soils on the plateau are well drained, reddish-brown heavy clay and classified as nitosols and luvisols. There are pockets of regosols within the plateau The foot slopes have poorly drained, dark gray, heavy clay soils The flood plain of the study area has reddish brown, clay loam to clay soils (fluvisols). Experimental plot I (EP I) is on a vertic luvisol, while experimental plot II (EP II) is on an eutric nitosol

3.1.5 Land use/land cover and natural vegetation of the study area

At very high altitude (upper Wurch, above 3700 m asl), very little cultivation is found because of low temperatures. The area is covered with shrubs and grasses and mainly used for grazing Therefore only little attention has been given in this study The Wurch (3200-3700 m asl) is moderately cultivated with barley and potato as the main characteristic crops Steep slopes occur in this zone, which are used for grazing

The Dega zone (2300-3200 m asl) is moderately to intensively cultivated Dominant crops are barley, teff (*Eragrostis abyssinica*), wheat and horse bean In the lower parts of the Dega zone teff, wheat, horse bean, chickpea, lentil, Niger seed and vetch are the main crops

The intensity of cultivation in the Blue Nile gorge (below 2300 m asl) decreases with altitude from moderate in the Weyna Dega zone to sparse in the Kolla zone The steep to very steep escarpments in the gorge and most of the area below 1500 m asl (Kolla) is covered with degraded woodland shrub-grass land. Dominant crops in the Weyna Dega (1500-2300 m asl) are teff, wheat, chickpea, lentil and sorghum. Below 1500 m asl (Kolla) the main crops are teff and sorghum.

Some of the most common natural vegetation species found in the area are *Hagenia abyssinica*, *Acacia spp.*, *Rubus aretulus*, *Schefflera abyssinica*, *Augaria sulicifolia*, *Erythrina tomantosola*, *Embelia schimperia*, *Bersama abyssinica*, *Rosa abyssinica*, *Cordia africana*, *Croton macrostachys*, *Dodonia viscosa* and *Euclea schimper*.

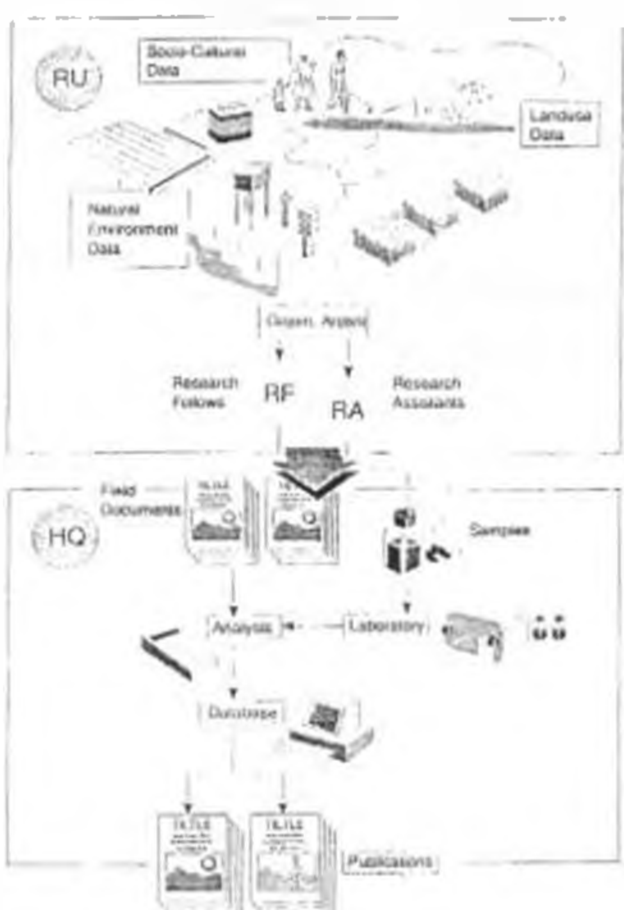
The dominant land use practiced in the Anjeni soil conservation research catchment were cultivation of cereals, pulses and oil crops, and fallow, grassland and bushlands. The dominant crops grown in this area include teff, maize, barley and wheat. Some of the remnant natural vegetation in the catchment includes *Hagenia abyssinica*, *Acacia spp.*, Bamboo, *Rubus aretalus*, *Augaria sulicifolia* and *Rosa abyssinica*.

3.2 Data collection at the Anjeni Research Unit

Sections between 3.2.1 and 3.2.5 describe the data flow, experimental setup and methods and procedures used by Soil Conservation Research Project (SCRP).

3.2.1 Research facilities and monitoring network of the Anjeni Research Unit

The Anjeni research station is equipped with meteorological instruments for monitoring temperature, evaporation, rainfall, wind and sun shine. Soil loss and runoff measurement are recorded from micro-plots (1 m x 3 m), test plots (2 m x 15 m), experimental plots (6 m x 30 m), river discharge and land use/cover. Crop production data has been collected at the end of each production year



Source, SCRP data base, 1989

Figure 4 Data flow

The data flow in SCRP is shown in figure 4 above. The upper half of the diagram illustrates the process of data collection in the field. From here the researcher can analyze and interpret the data in the form of progress or research report

3.2.2 Description of the Experiment

The experimental plots (EPs) consist of two components, a field area (plot) in which the erosion process can take place, and a collection tank in which the eroded soil and the runoff can be quantitatively assessed. Experimental plot I (EP I) has a slope of 28% and experimental plot II (EP II) has a slope of 12% The soil conservation experiments are conducted on 6m x 30m plots (the standard size of conservation experiment plots used in the soil conservation research programme) The plots are set on a cultivated field The field is homogenous in terms of slope (%), previous erosion, and soil type and topsoil depth.

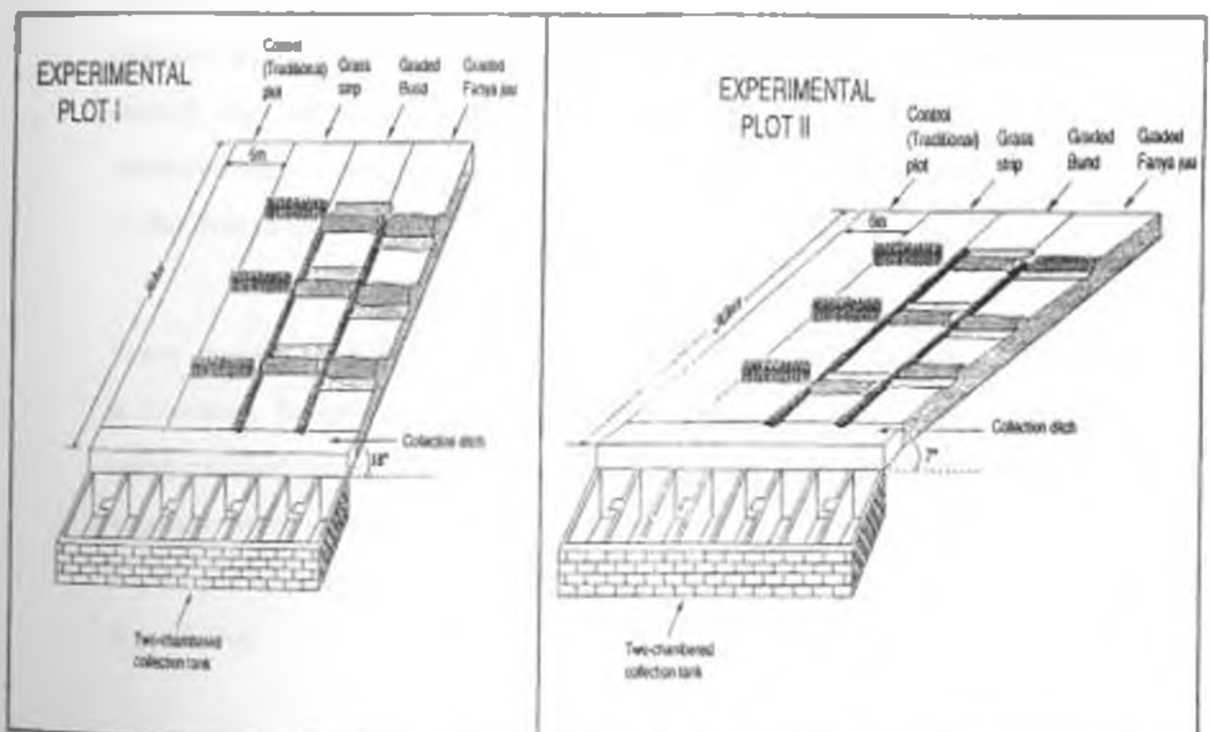


Figure 5 Experimental Plot layout

In each of these experimental plots the aim is to compare the effect of different conservation measures on surface runoff and soil loss Four of the plots are treated with structural conservation measures and one is left as an untreated (control) plot. The types of soil conservation treatment tested are "graded grass strip", "graded fanya juu", "graded bund" and the "traditional farming (control plot)" (Figure 5).

Corrugated iron sheets border the soil conservation experimental plots A pair of tanks with capacities of $1m^3$ each is installed to collect runoff and sediment from these plots The corrugated iron sheets are removable whenever the farmer wants to cultivate his farm land

3.2.3 Monitoring runoff and soil loss

Measuring and recording the water and sediment collected in the tanks after every storm monitor the runoff and soil losses Each plot is connected to a cemented collection ditch and a two chambered runoff and sediment collection tank both situated at the down slope end of the plot. Between the first and second tank of each plot, there is a slot divisor with ten holes designed in such a way that only one-tenth of the over flow from the first tank enters the second one whenever a heavy storm with much runoff occurs. This method enables measurement of runoff and soil loss for heaviest storms All tanks have corrugated iron covers so that rain drops do not enter into them directly

Every morning after each rainfall period (event), the depth of the water in the collection tanks is measured Runoffs in millimeters and as percentages of rain for each plot were determined using standard programme adopted by SCRP The soil accumulated in the sediment tanks is weighed when wet Wet samples collected after each rainfall event were sun dried in the station and taken to the soil laboratory for oven dry weights and later used to calculate the total dry soil loss

3.2.4 Monitoring crop yield

When the crop in the experimental plots was ready for harvest, it was cut and collected from each section of the entire plot in the same way the farmers in the catchment do collections That is a crop from each plot harvested and threshed by hand The grains were air dried for 20 days, weighed and recorded in the harvest sample for each plot. The areas occupied by the conservation structures were exclusive in the calculations of yield data

3.2.5 Land use/land cover monitoring

The special and temporal distribution of land use/land cover was assessed using the catchment base map with a scale of 1:5,000. The whole land use/land cover information had been transferred into the base map through ground truthing The information from the base map was converted into numerical value using planimetric measurement

3.3 Secondary Data used for this study

Eight years of data (runoff, soil loss, crop yield, rainfall, erosivity and land use) were used to evaluate the performances of different soil and water conservation measures. On grass strips, only three years of data was available The monthly and annual runoff and soil loss on the control plot, graded fanya juu and graded bund for the period 1984 to 1992 and on grass strips for the period 1989 to 1992 were obtained from soil conservation research project records Rainfall and erosivity data were also obtained from the same record. Data was not available for 1991 due to civil war Rainfall and erosivity for Anjeni research unit were evaluated using the outline given in appendix 1

3.4 Estimating missing data

Where a value is missing or unusable, where there has been an obvious recording error, a method developed by Yates (1936) is available for estimating such missing data

$$Y = \frac{rR + tT - G}{(r-1)(t-1)}$$

Where

Y = the required value
r and t = number of replicates and treatments
R and T = totals of observed values in replication and treatment containing the missing unit
G = grand total of the observed values

An estimated value of a missing value does not supply additional information during interpretation; it only facilitates the analysis of the remaining data.

3.5 Statistical analysis

All the data were subjected to a statistical analysis in order to identify the possible relationship between soil loss/runoff and soil conservation measures, and crop yield and soil conservation measures. The analysis was carried out using Steel and Torrie (1980) method for unequal replications and time series replication (Appendices 3 - 7) at 1 % level of significant. A correlation coefficient was used to determine the strength of relationship between runoff and soil loss (dependent variables) and rainfall amount and energy (independent variables), and soil loss and crop yield.

The one-way 'analysis of variance' (ANOVA) was used to find out whether the observed variations on runoff, soil loss and crop yield were statistically significant or not using Fisher (F) test calculated using the outline given in table 7. The experiment was one way because the treatment is the only criteria for classifying the data. For example soil and water conservation measures were considered as the only criteria affecting soil loss and therefore other environmental factors that affect soil losses were not used during the analysis.

Table 7 Outline of the analysis of variance for one way experiment

Source of Variance	Degree of Freedom	sum of Squares	Mean Square	Computed F	Tabulated F 1%
Treatments	t - 1	$\Sigma Y_i^2/r$ - C.F	tSS/t - 1	tMS/EMS	
Error	t(r - 1)	TSS - tSS	ESS/t(r - 1)		
Total	rt - 1	ΣY_{ij}^2 - C.F			

Where:

r = Number of replications per treatment
t = Number of treatments
Y_i = Treatment total
C.F = Correlation factor = G^2/rt
G = Grand total
tSS = Treatment sum of squares
tMS = Treatment mean squares
ESS = Error sum of squares
EMS = Error mean squares
TSS = Total sum of squares
Y_i^2 = Sum of treatment squares
F = Fisher test

Sample calculation using the outline (Table 7) is given in appendix 7

For further analysis Duncan's Multiple Range Test (Duncan, 1955) was used to determine differences between treatments (Table 8). In this technique, the means which are underscored by the same line are not significantly different, otherwise they are significantly different (Appendix 8); (Steel and Torrie, 1980). For the test tabulated values are available in the above mentioned source and begin by computing least significant range, R_p.

$R_p = q_{\alpha 1} S_{\bar{y}}$; $\alpha^1 = 1 - (1 - \alpha)^{p-1}$ OR $\alpha^1 = 1\%$, $p = 2,3,\ldots t$

Table 8 Outline of computing differences for Duncan's New Multiple Range Test

P	2	3	4
$q_{\alpha 1}$			
R_p			

Where -
R_p (least significant range) = $q_{\alpha 1} S_{\bar{y}}$
$\alpha^1 = 1 - (1 - \alpha)^{p-1}$ OR $\alpha^1 = 1\%$
P = 2,3 and 4 [number of treatments (t) - 1]
$q_{\alpha 1}$ = Tabulated value corresponding to its degree of freedom and number of means for range being tested
$S_{\bar{y}} = \sqrt{EMS/r}$

3.6 Runoff, soil loss and crop yield index (%)

For easy comparison of runoff loss, soil loss or crop yield values between traditional farming (control plot) and soil conservation techniques, the following equations have been used where necessary in this study

$$R_I(\%) = \frac{R_T}{R_C} X100$$

$$S_I(\%) = \frac{S_T}{S_C} X100$$

$$Y_I(\%) = \frac{Y_T}{Y_C} X100$$

Runoff (R_I), soil loss (S_I) and yield index (Y_I) in percent, as used by the author refers to the ratio of runoff (R_T), soil loss (S_T) and crop yield (Y_T) in treatments and runoff (R_C), soil loss (S_C) and crop yield (Y_C) respectively, in the traditional farming (control plot)

3.7 Questionnaire survey

3.7.1 Agro-climatic zonation

The study was conducted across different agro-climatic zones (ACZ) to assess whether certain soil and water conservation measures are more sustainable in some ACZ than others, perhaps because of water shortage or surplus Figure 6 shows the cross section of the study area.

According to Soil Conservation Research Programme, traditional agro-climatic zones are classified as follows

500 - 1500m asl	*Kolla*
1500 - 2300m asl	Weyna Dega
2300 - 3200m asl	Dega
3200 - 3700m asl	Wurch

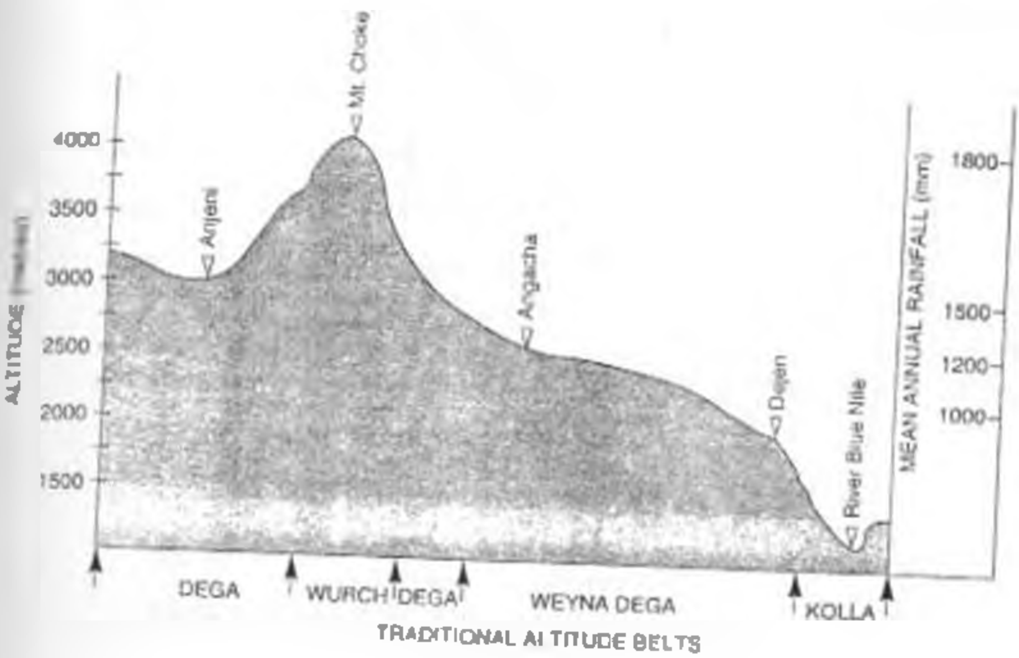


Figure 6 Cross-section of agro-climatic zones

The cross-section of the study area was delineated approximately 3700 m asl around Feres Bet and 1000 m asl in Blue Nile Gorge at the upper and lower parts of the study area respectively These include the Blue Nile Gorge at the lower altitude, the Gojam plane in the middle altitude and hilly and rugged topography at the upper altitude

3.7.2 Sampling

From each agro-climatic zone, one representative peasant association (PA) was randomly chosen from the lists of the PA, which is available in the District agricultural offices. Forty households were chosen randomly from the list of PAs in these zones (ten farmers from each zone) in order to find out if particular soil and water conservation measures were especially attractive to farmers In addition to the agro-climatic differences, cultural variations within the zones were also considered in the sampling area as specific soil and water conservation measures may be suited to the needs of some groups more than the others Consideration was also given to differences within the farming community and the suitability of soil conservation measures to the farmers in different socio-economic setups

The decision on the number of household interviewed was based the available resources (time and money). From each PA, 10 households were chosen systematically: three households, which were relatively poor, three households relatively rich, and four households, which were considered to be in the middle of these two classes. These classes were based on the following criteria (modified from Ludi, 1997):

- Rich - Sell cereals and do so frequently, have two oxen and large herds of animals (cattle, horses, mules, sheep and bees).
- Average - Cereal is usually neither bought nor sold, household production is just at the level of self sufficiency. Have two oxen, no herds, and do not have many different types of animals
- Poor. - Buy cereals in order to have enough food, have a maximum of one ox and rarely have other animals, except few sheep

3.7.3 The questionnaire

An overview of the history of soil and water conservation in each PA was obtained through questionnaire interview and formal and informal discussion with the community leaders, individual households and development agents (DAs). The main aim of the household interview was to identify the attitudes of farmers to different soil and water conservation measures and their reasons for using or rejecting specific soil and water conservation measures. It was hoped that this approach would help in studying the spread and constraints for the adoption of technically effective soil and water conservation measures that had been obtained by the SCRP through experimentation and demonstration. The questionnaire that was used in the evaluation of past soil and water conservation techniques in Gojam highlands is given in appendix 11.

3.7.4 Analysis of questionnaire results

The questionnaire was arranged in a way that conversion was possible into numerical values. Therefore the number of respondents answered yes or no; high or low; and those farmers having physical structures or traditional ditches or combination physical structures with traditional ditches, etc., were counted and converted into percentage values for easy interpretation

4 RESULTS

4.1 Results of the Anjeni Research Unit

4.1.1 Land use/land cover and natural vegetation

Lands that were under cultivation showed increasing trends since 1984, i.e from 61% in 1984 to 76% by 1992. Fallow land increases from 1 percent in 1984 to 15 percent by 1990 and again it dropped to 5 percent by 1992 Grassland showed a declining picture In 1984 cover was about 38 percent and it reduced to 26 percent by 1986 and again 32 % in 1987 and the lowest value (10 percent) was measured in 1989 (Table 9).

Table 9 Land use/cover as mapped in the Anjeni research unit

Year	Cultivated (%)	Fallow (%)	Grass (%)	Others (%)	Total (%)
1984	61	1	38	–	100
1985	61	2	37	.	100
1986	62	6	26	6	100
1987	64	3	32	1	100
1988	69	2	29		100
1989	79	5	10	6	100
1990	69	15	12	4	100
1992	76	5	18	1	100

Note: Others (Village, Research Station, Clinic, School, River Gullies, etc)

The conversion of grassland in to cultivated land showed an increasing trend Therefore use of soil and water conservation structures are indispensable for sustainability of land productivity

4.1.2 Rainfall and erosivity of the Anjeni research unit

4.1.2.1 Monthly variation

Table 10 presents monthly rainfall parameters Anjeni area is commonly known as having relatively high rainfall and long growing period from May to October Higher precipitation causes higher erosivity ($y = 0.4157x - 5.9587$, $r = 0.99$; y is mean monthly erosivity [J/mh] and x is mean monthly rainfall [mm]). Therefore erosivity is higher from May to October

The rainfall distribution during this period (May to October) varies between 106.2 and 398.2 mm with a peak rainfall (398.2 mm) and erosivity (173.5 J/mm/m2) in July. This period is contributing about 90% of the annual rainfall (Figure 7). About half of the annual rainfall is occurring in May, June and July and this is the period when seed bed preparation is carried out and the entire catchment is bare. The smoothened surface is exposed to heavy rains without vegetation cover. The difference in runoff and soil loss between months is due to variation in rainfall, erosivity, land use/cover, and slope and crop types. The highest erosive rainfall is measured in July (Table 10), in most cases it corresponds with highest runoff and soil loss.

Table 10 Mean monthly rainfall and erosivity (1984 - 1992)*

Month	Rainfall (mm)	Percent of annual	Erosivity (J/mm m2)	Percent of annual
January	14.90	0.92	9.7	1.60
February	14.6	0.90	3.0	0.50
March	37.5	2.32	6.0	1.00
April	52.5	3.20	13.6	2.30
May	106.2	6.60	38.3	6.40
June	240.1	14.80	93.5	15.60
July	398.2	24.60	173.5	28.90
August	355.7	22.00	137.5	22.90
September	242.6	15.00	76.7	12.80
October	109.8	6.80	45.8	7.60
November	28.0	1.70	2.6	0.43
December	17.7	1.10	0.8	0.13

* excluding 1991

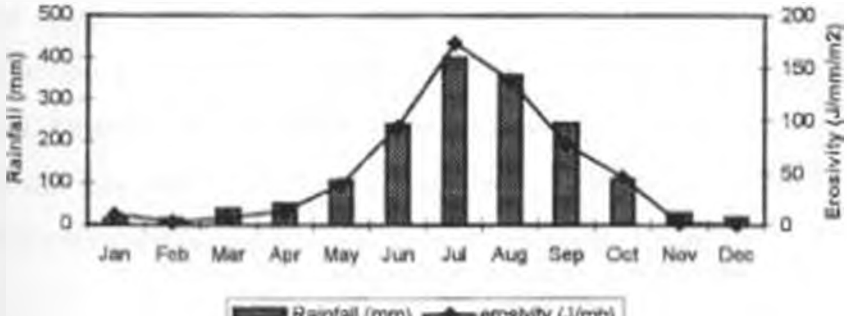


Figure 7 Mean monthly rainfall and erosivity of the Anjeni research unit

4.1.2.2 Yearly variation

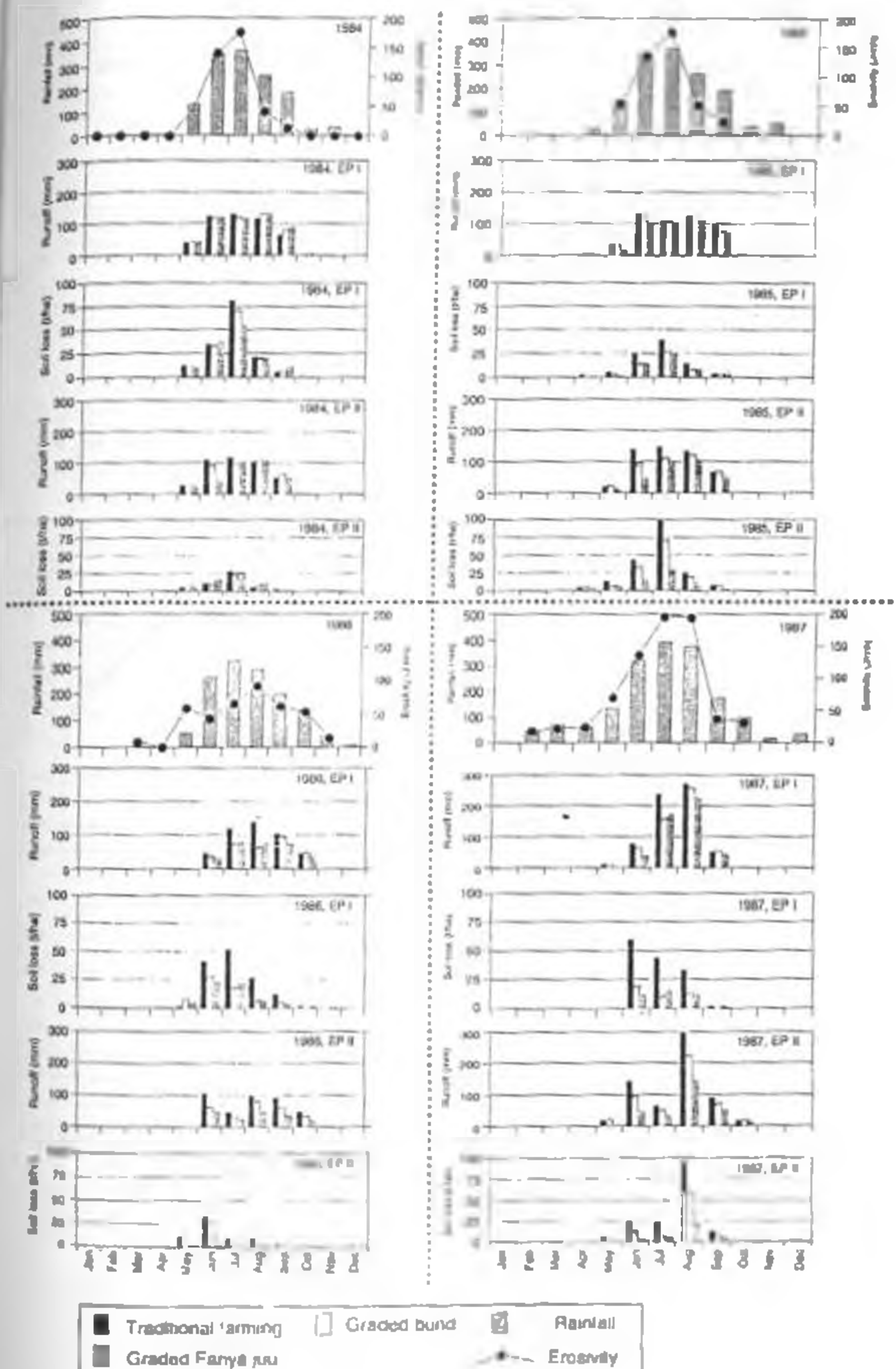
The lowest annual rainfalls were 1372 mm in 1986 and highest 1855 mm in 1988 with the respective erosivity of 394 J/mm/m2 and 675 J/mm/m2. The extreme annual data that occurred in 1988 (1855 mm) is varying from the mean annual rainfall by 216 mm. The variation of the highest annual erosivity from the annual mean is around 265.5 J/mm/m2 (Table 11). The regression equation ($y = 0.7245x - 578.72$; $r^2 = 0.77$; y is annual erosivity [j/mh], x is annual rainfall [mm]) showed that erosivity is linearly increased with increases in rainfall.

Table 11 Annual rainfall and erosivity

Year	Precipitation (mm)	Erosivity (J/mm/m2)
1984	1432	415.3
1985	1556	552.1
1986	1372	394.0
1987	1811	731.2
1988	1855	675.3
1989	1648	531.1
1990	1668	874.3
1992	1770	696.9

4.1.3 Monthly runoff and soil loss in Experimental Plots

The impact of monthly rainfall distribution and its energy on runoff and soil loss showed similar trends in all years on both sites. The highest runoff and soil loss occurring in June, July, August and September, except June in 1988, where high rainfall and high erosivity did not produce significant runoff and soil loss on all treatments on both sites. In 1989 and 1990, however, the distribution of rainfall in June was low and consequently the runoff and soil loss were lower in all treatments. In general higher runoff and soil losses were observed on traditional farming (control plot) in all rainy months (Figure 8).


1984
Rainfall (mm)
1984, EP I
Runoff (mm)
Soil loss (t/ha)
1984, EP II
1985, EP I
1985, EP II
1986
1986, EP I
1986, EP II
1987
1987, EP I
1987, EP II
Traditional farming
Graded bund
Rainfall
Graded Fanya juu
Erosivity

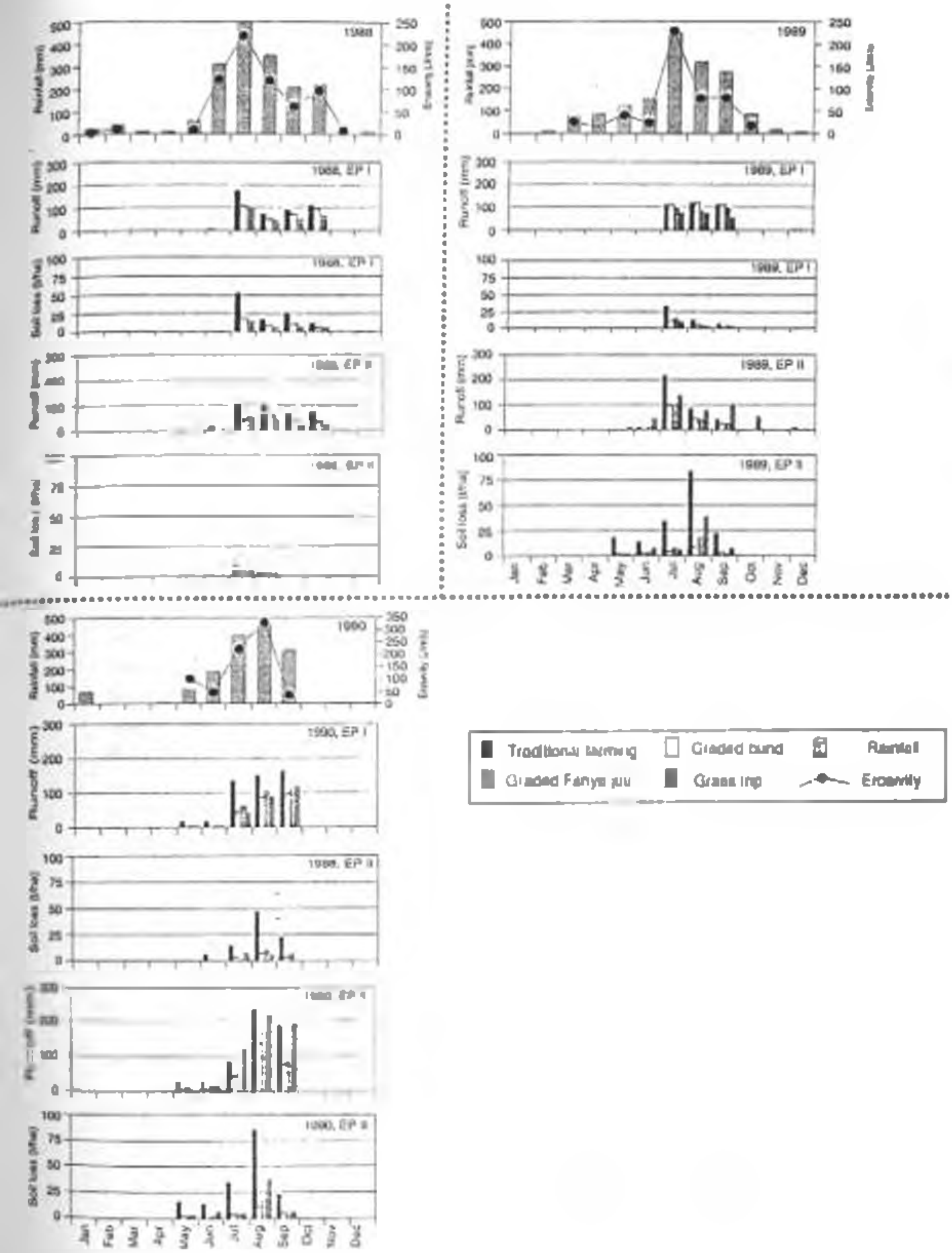


Figure 8 Monthly rainfall, erosivity, runoff and soil loss on EP I and EP II

4.1.4 Mean monthly runoff and soil loss in Experimental Plot I

Except in September and October when graded fanya juu showed high values of runoff and soil loss the control plot recorded highest amount throughout the year. Grass strips showed a better performance in runoff and soil loss reduction, while graded bund and graded fanya juu showed more or less a similar trend in reducing soil loss (Figures 9 and 10). The highest runoff (134.5 mm) and soil loss (33.6 t/ha) occurred in July in the traditional farming (control plot) (Table 12).

Table 12 Mean monthly runoff (mm) and soil loss (t/ha)

Month	Traditional farming		Graded bund		Graded fanya juu		Grass strip	
	Runoff	Soil Loss	Runoff	Soil Loss	Runoff	Soil Loss	Runoff	Soil Loss
January	3.4	0.4	2.1	0.0	2.4	0.0	0.0	0.0
February	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
April	0.8	0.0	0.3	0.0	0.0	0.0	1.2	0.2
May	8.0	4.3	3.1	2.7	1.8	1.8	2.1	0.0
June	31.3	21.5	23.3	15.1	7.5	10.2	12.7	6.2
July	134.5	33.6	81.2	11.0	75.7	12.9	52.5	10.3
August	126	23.4	89.6	7.8	95.1	9.3	74.2	7.8
September	80.3	13	66.6	4.0	110.2	7.1	66.8	3.2
October	43.9	5.4	37.7	2.4	41.3	2.6	5.7	0.0
November	0.0	0.0	0.5	0.0	2.1	0.1	19.5	0.4
December	7.1	0.0	2.0	0.0	2.0	0.0	0.6	0.0

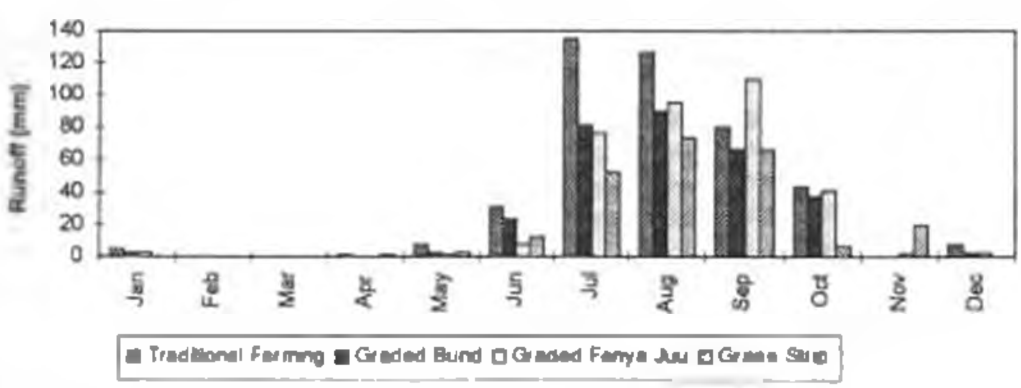


Figure 9 Mean monthly runoff

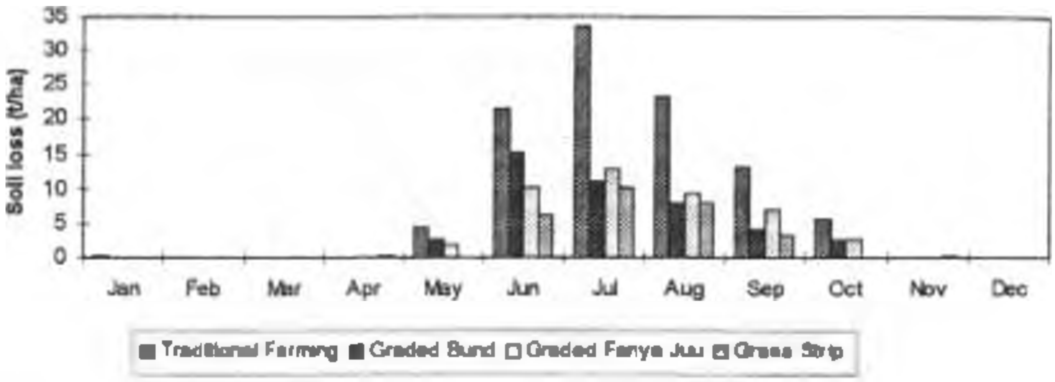


Figure 10 Mean monthly soil loss

4.1.5 Annual runoff and soil loss in Experimental plot I

A declining trend on runoff and soil loss was observed on soil conservation structures since the establishment of the experiments compared to the traditional farming In 1984 runoff was 99 and 98% on graded bund and graded fanya juu respectively. Soil loss was 90 and 85% on graded bund and graded fanya juu respectively. In 1992, however, runoff and soil loss reduced around 50% on graded bund and graded fanya juu compared to the traditional farming

On average, graded fanya juu performed slightly better than graded bund Both graded fanya juu and graded bund reduced soil loss by 54 and 52.5% respectively when compared with the control plot A three years result on grass strip showed that runoff and soil loss reduced by 50 and 75% respectively compared to the traditional farming (Table 13).

Table 13 Annual runoff (mm) and soil loss (t/ha)

Year	Treatments	Runoff		Soil Loss	
		(mm)	index (%)	(t/ha)	index (%)
1984	Traditional farming	510.7	100	161.1	100
	Graded bund	508.0	99	145.5	90
	Graded fanya juu	501.3	98	137.4	85
1985	Traditional farming	533.0	100	98.0	100
	Graded bund	470.0	88	60.0	61
	Graded fanya juu	420.0	78	56.0	57
1986	Traditional farming	470.7	100	137.7	100
	Graded bund	338.6	72	68	49
	Graded fanya juu	319.7	68	54.6	40
1987	Traditional farming	619.6	100	138.6	100
	Graded bund	517.0	83	45.6	33
	Graded fanya juu	461.1	74	39.2	28
1988	Traditional farming	481.0	100	111.4	100
	Graded bund	345.0	72	41.3	37
	Graded fanya juu	282.2	59	35.6	32
1989	Traditional farming	358.5	100	59.2	100
	Graded bund	210.9	59	19.2	32
	Graded fanya juu	268.5	75	25.4	43
	Grass strip	219.9	61	13.8	23
1990	Traditional farming	502.1	100	103.7	100
	Graded bund	241.6	49	15.2	15
	Graded fanya juu	291.7	58	23.4	23
	Grass strip	262.7	52	15.7	15
1992	Traditional farming	533.8	100	167.1	100
	Graded bund	260.8*	49	71.1*	43
	Graded fanya juu	259.5*	49	80.7*	48
	Grass strip	343.3	64	61.4	37

* Estimated data using Yates method (1980) (as shown in section 3.4)

Traditional Farming (control plot): The highest (619.9 mm) and lowest (358.5 mm) annual runoff were measured in 1987 and 1989 respectively. The highest (167.1 t/ha) and the lowest (59.2 t/ha) annual soil loss was measured in 1992 and 1989 respectively (Table 13; Figures 11 & 12).

Graded bund. The highest (517 mm) and the lowest (210.9 mm) runoff from the graded bund were measured in 1987 and 1989 respectively. The annual soil loss showed a declining trend. The highest value (145.5 t/ha) and the lowest (15.2 t/ha) values were recorded in 1984 and 1990 (Table 13; Figures 11 & 12).

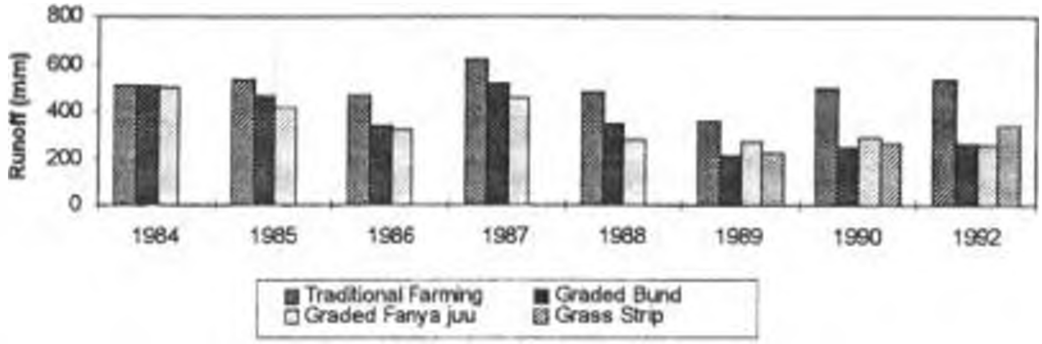


Figure 11 Annual runoff under different soil and water conservation measures

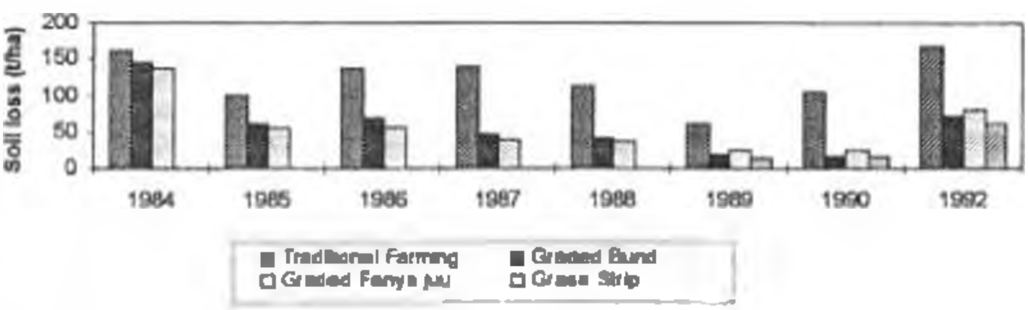


Figure 12 Annual soil loss under different soil and water conservation measures

Graded fanya juu: the highest annual runoff (501.3 mm) was in 1984 and the lowest (259.5 mm) 1992. The annual soil loss on the graded fanya juu generally declined with time; i.e., the highest (137.4 t/ha) and lowest (23.4 t/ha) annual soil loss was measured 1984 and 1990 respectively (Table 13; Figures 11 & 12).

Grass strip There was an increase in both annual runoff and annual soil loss since 1989 on grass strips The highest annual runoff (343.3 mm) was measured in 1992 and the lowest (219.9 mm) in 1989 A similar trend was also observed on the mean soil loss (Table 13; Figures 11 & 12).

4.1.6 Mean monthly runoff and soil loss in Experimental Plot II

The highest mean monthly runoff (153.4 mm) and mean monthly soil loss (33.3 t/ha) was measured on the traditional farming (control plot) in August (Table 14; Figures 13 & 14). The lowest mean monthly runoff and mean monthly soil loss on the traditional farming plots indicate that there was a danger of waterlogging in such gentle slopes. Therefore to drain safely this excess water out of the cultivated field land users practice a combination of traditional ditches with bunds or traditional ditches alone.

Table 14 Mean monthly runoff (mm) and soil loss (t/ha)

Month	Traditional farming		Graded bund		Graded fanya juu		Grass strip	
	Runoff	Soil Loss	Runoff	Soil Loss	Runoff	Soil Loss	Runoff	Soil Loss
January	12.8	0.9	2.1	0.0	2.2	0.0	0.0	0.0
February	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
April	0.5	0.0	4.7	0.0	0.2	0.0	0.6	0.0
May	14.5	12.4	19.7	7.0	7.8	2.0	10.5	4.1
June	63.5	14.9	57.5	8.5	26.2	14.1	38.3	10.6
July	98.0	17.7	71.3	6.7	51.5	3.5	53.8	3.3
August	153.4	33.3	119.8	17.4	85.6	8.4	123.2	10.0
September	91.8	8.4	68.3	1.6	52.2	1.4	82.8	3.0
October	38.6	0.9	27.0	0.2	15.3	0.3	35.6	0.3
November	1.4	0.0	0.0	0.0	0.0	0.0	0.2	0.0
December	8.1	1.5	1.1	0.2	1.2	0.1	1.1	0.0

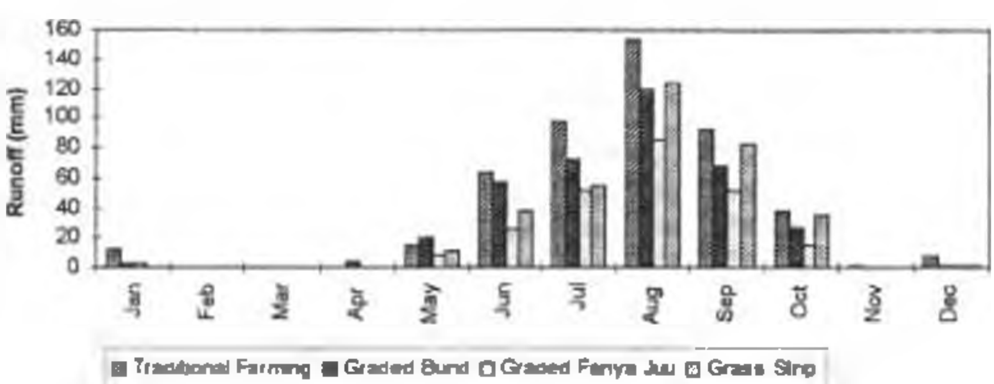


Figure 13 Mean monthly runoff

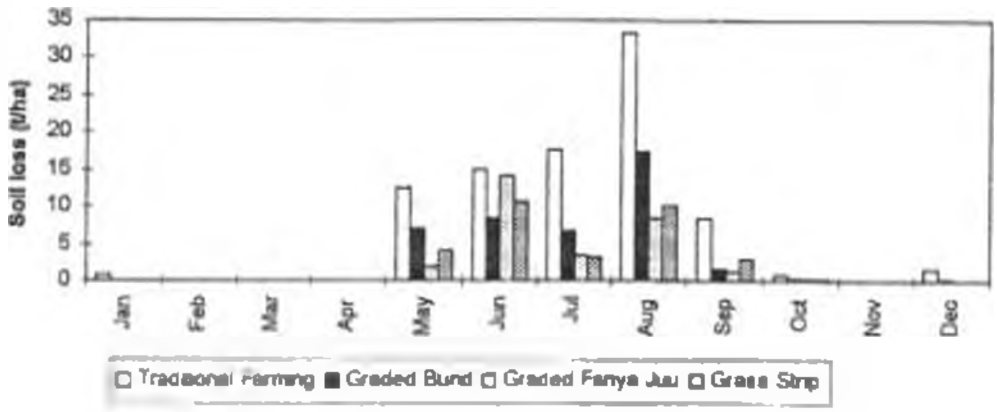


Figure 14 Mean monthly soil loss

4.1.7 Annual runoff and soil loss in Experimental plot II

A declining trend was observed on runoff and soil loss on soil conservation structures compared to the traditional farming. In 1992, however, graded bund showed the highest soil loss (167%) compared to traditional farming. On average graded bund and graded fanya juu reduced runoff by 34 and 40% respectively. Soil loss reduced by 32 and 67% on graded bund and graded fanya juu respectively. Higher average runoff (104%) was observed on grass strip compared to traditional farming. Soil loss on grass strip reduced by 22% compared to traditional framing (Table 15).

Traditional Farming (control): The highest annual runoff (645.0 mm) was measured on the control plot in 1987 and the lowest (201.3 mm) in 1992. However, the highest annual soil loss (189 t/ha) was measured in 1985, whereas the lowest annual soil loss corresponds to the lowest rainfall (i.e., the lowest soil loss that was measured in 1992 was 11.3 t/ha) (Table15, Figures 15 & 16).

Table 15 Annual runoff (mm) and soil loss (t/ha)

Year	Treatments	Runoff		Soil Loss	
		(mm)	index (%)	(t/ha)	index (%)
1984	Traditional farming	441.2	100	53.2	100
	Graded bund	401	91	51	96
	Graded fanya juu	374.4	85	55	103
1985	Traditional farming	558	100	189	100
	Graded bund	470	84	144	76
	Graded fanya juu	372	67	63	33
1986	Traditional farming	442.2	100	65.4	100
	Graded bund	305.8	69	44.7	68
	Graded fanya juu	210.1	47	13.8	21
1987	Traditional farming	645	100	168.5	100
	Graded bund	477.9	74	90.7	54
	Graded fanya juu	283.5	44	29.7	18
1988	Traditional farming	391.3	100	16.5	100
	Graded bund	230.5	59	7.2	44
	Graded fanya juu	173.1	44	5.7	36
1989	Traditional farming	363	100	25.9	100
	Graded bund	168.9	46	7.1	27
	Graded fanya juu	159.7	44	5.8	22
	Grass strip	432.5	118	43.9	169
1990	Traditional farming	568	100	175.5	100
	Graded bund	265.2	47	17.6	10
	Graded fanya juu	370.1	65	30.4	17
	Grass strip	592.1	104	61	35
1992	Traditional farming	201.3	100	11.3	100
	Graded bund	110.7	55	18.9	167
	Graded fanya juu	166.2	83	1.7	15
	Grass strip	179.5	89	3.4	30

Graded bund: Like the control plot, the highest annual runoff (477 9 mm) and the lowest annual runoff (110.7 mm) was measured in 1985 and 1992 respectively Moreover, the highest (144 t/ha) and lowest (7 1 t/ha) annual soil loss was measured in 1985 and 1989 respectively (Table 15, Figures 15 & 16). The graded bund reduced the annual runoff and soil loss by 11 and 59% respectively compared to the control plot

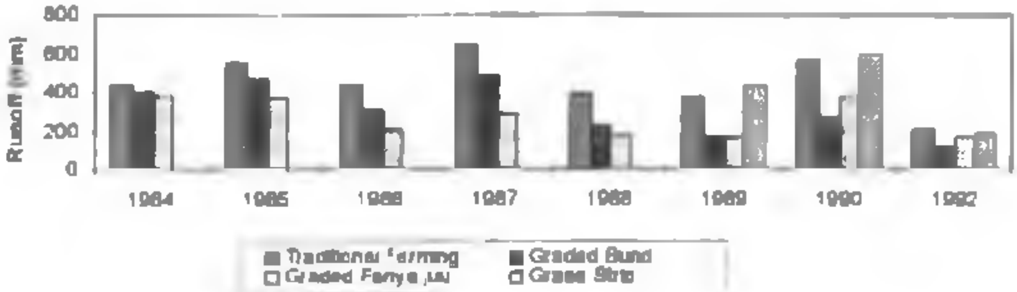


Figure 15 Annual runoff under different soil and water conservation measures

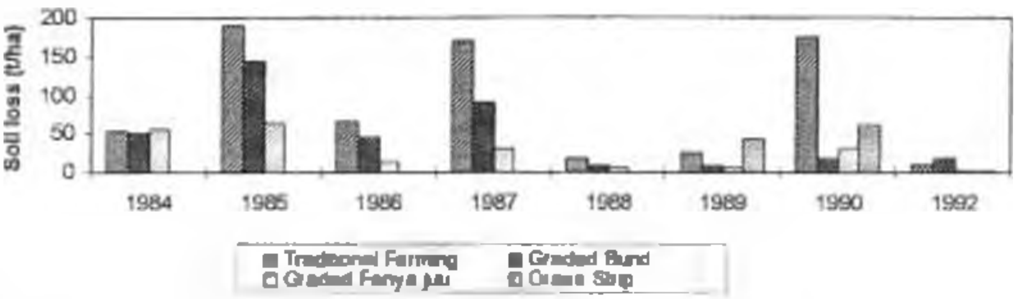


Figure 16 Annual soil loss under different soil and water conservation measures

Graded fanya juu: Unlike traditional farming and graded bund, the highest (374.4 mm) and lowest annual runoff (159.7 mm) on graded fanya juu was measured in 1984 and in 1989 respectively. On the contrary, the highest (63 t/ha) and the lowest annual soil loss (1.7 t/ha) were measured in 1985 and 1992 respectively (Table 15, Figures 15 & 16). Fanya juu showed the highest reduction in both annual runoff and soil loss. Runoff and soil loss was reduced by 42 and 71% respectively when compared to the control plot.

Grass Strip: The highest (591.2 mm) and lowest annual runoff (179.5 mm) were measured in 1990 and 1992 respectively. Both the highest and lowest annual soil loss corresponds to the mean highest and lowest annual runoff respectively; i.e., the highest soil loss was measured in 1990 and the lowest one in 1992 (Table 15; Figures 15 & 16)

4.1.8 Cumulative runoff and soil loss for Experimental Plots

Table 16 gives the cumulative runoff and soil loss for the eight year period except grass strips for which the data was available for only three years. The runoff and soil losses for the control plots are higher than for the introduced physical structures at both sites (EPI and EP II). The highest runoff and soil loss reduction was observed on the grass strip in EP I by 41 and 73 percent respectively. Whereas in EP II higher runoff and soil loss reduction was observed on graded fanya juu, by 42 and 71 percent respectively. Graded fanya juu and graded bund reduced runoff by 30 and 28 percent and soil loss by 54 and 52 percent in EP I respectively. In EP II, however, graded fanya juu and graded bund reduced runoff by 42 and 33 percent and soil loss by 71 and 46 percent respectively compared to the control plot

Table 16 Cumulative runoff and soil loss

Treatments	EP I (28 % gradient)				EP II (12 % gradient)			
	Runoff		Soil loss		Runoff		Soil loss	
	(mm)	index (%)	(t/ha)	index (%)	(mm)	index (%)	(t/ha)	index (%)
Traditional farming	4011	100	977	100	3612	100	705	100
Graded bund	2894	72	466	48	2410	67	381	54
Graded fanya juu	2804	70	452	46	2109	58	205	29
Grass strip*	826	59	91	27	1204	33	108	15

* Three years data (1989,1990 and 1992) and the percentage were calculated based on the corresponding data from the traditional farming.

4.1.9 Runoff and soil loss summary for Experimental Plots

The variation in runoff and soil loss indicates that there were considerable monthly and annual variations in runoff and soil loss between treatments. The average soil loss in July in EP I was 42% on the traditional farming, 46% on graded bund, 47% on graded fanya juu and 57% on graded grass strip of the mean annual soil loss. In EP II, however, the average soil loss in July was higher compared to the EP I. The average soil loss in July in EP II was 67% on the traditional farming, 80% on the graded bund, 83% on a graded fanya juu and 74% on the graded grass strip of the mean annual soil loss

EP I: The one way statistical analysis showed that there was significant difference between treatments at 1 % level of significance (Appendix 4). Duncan's Multiple Range Test (Appendix 8) showed that all treatments are significantly different from control plot at 1 % level of significance. The higher means indicate the high runoff and soil losses in the traditional farming. A lower mean showed that there is a better performance in runoff and soil loss reduction on the physical structures as compared to the traditional farming.

EP II On gentle slope fields, there were also significant differences between treatments (Appendix 4). Further statistical analysis showed that at 1 % level of significance, there was a significant difference on runoff reduction between treatments Duncan's Multiple Range Test (Appendix 8) also showed that at 1 % level of significance, there was no significant difference on soil loss reduction between treatments and traditional farming, except graded fanya juu which was significantly different from the control plot.

The low amount of soil loss on graded fanya juu was due to its ability to drain excess water and leave the sediment behind, a function that is intended to fulfill as a soil conservation measure.

4.1.10 Correlation (r) of rainfall amount and erosivity versus soil loss

Tables 17 and 18 shows the correlation between rainfall amount, erosivity and soil loss for experimental plot I and II. The correlation value is very low except on grass strip for rainfall versus soil loss. This indicates that the main causes of soil erosion are not the amount of rainfall and its energy Runoff and soil losses, depend not only on rainfall amount and erosivity but also on land use/land cover, farming system and other cultural practices.

Table 17 Relation between rainfall and soil loss

	Treatments	Regression equation	Correlation coefficient (r)
EP I	Traditional farming	y = -0.022x + 139.51	0.11
	Graded bund	y = - 0.1233x + 260	0.53
	Graded fanya juu	y = - 0.101x + 222.13	0.47
	Grass strip	y = 0.409x - 727.37	0.99
EP II	Traditional farming	y = - 0.0223x + 124.79	0.05
	Graded bund	y = - 0.0661x + 156.01	0.24
	Graded fanya juu	y = - 0.0594x + 123.08	0.45
	Grass strip	y = - 0.4077x + 727.37	0.90

y is soil loss (t/ha/yr); x is annual rainfall (mm)

Table 18 Relation between erosivity and soil loss

	Treatments	Regression Equation	Correlation coefficient (r)
EP I	Traditional farming	y = -0.0223x + 135.68	0.10
	Graded bund	y = - 0.1523x + 150.95	0.61
	Graded fanya juu	y = - 0.1205x + 129.91	0.53
	Grass strip	y = 0.0025x + 28.567	0.01
EP II	Traditional farming	y = 0.1694x + 14.957	0.37
	Graded bund	y = - 0.0539x + 80.448	0.18
	Graded fanya juu	y = - 0.0283x + 42.849	0.20
	Grass strip	y = 0.057x - 1.0584	0.31

y is soil loss (t/ha/yr); x is erosivity (J/mh)

4.1.11 Runoff and soil loss relationships

On the gentle slope fields (EP II), a high runoff is required for a high soil loss to occur, while on the steep slopes (EP I), relatively low runoff causes high soil loss. On grass strips, high runoff resulted in high soil loss (r = 0.95 for EP I and r = 0.99 for EP II). Traditional farming and graded bund, however, showed relatively low correlation (r = 0.63 and r = 0.59 for EP I and r = 0.88 and r = 0.85 for EP II respectively). The relationships between runoff and soil loss on graded fanya juu showed similar values (r =0.56 in EP I and r = 0.57 in EP II). In general the correlations were high for both experimental plots (Table 19). The high correlation implies that the higher the runoff the higher the soil loss

Table 19 Relation between runoff and soil loss

	Treatments	Regression Equation	Correlation coefficient (r)
EP I	Traditional farming	$y = 0.3091x - 32.875$	0.63
	Graded bund	$y = 0.1975x - 13.205$	0.59
	Graded fanya juu	$y = 0.2197x - 20.454$	0.56
	Grass strip	$y = 0.4092x - 82.348$	0.95
EP II	Traditional farming	$y = 0.4841x - 130.41$	0.88
	Graded bund	$y = 0.3004x - 43.603$	0.85
	Graded fanya juu	$y = 0.2878x - 28.215$	0.57
	Grass strip	$y = 0.1415x - 20.68$	0.99

y is soil loss (t/ha); x is runoff (mm)

4.1.12 Crop yield on Experimental Plots

On average, considering the years only when the EPs were planted with the same crop in each set, the result tends to show higher yields for graded fanya juu and graded grass strip on both slopes compared to that of the traditional farming Wheat and barley grown in EP I showed a general decline trend in all treatments Niger seed, which was planted in 1989, showed a better yield on grass strip and graded fanya juu Niger seed yield on graded bund was lower than the yield on traditional farming Field peas showed similar values in all treatments except on graded bund in which it was reduced by 25% compared to the other treatments

In EP II graded fanya juu showed a better performance compared to the other treatments on horse bean yield Teff yield in this EP showed an increasing trend However, teff yield on traditional farming was higher than on the soil conservation structures. Grass strip showed a better performance on barley yield in EPI and other soil conservation structures, including traditional farming, showed similar values on barley yield

In EP I, the highest yield was measured in 1987 on the graded fanya juu (400%) and on the graded bund (300%), compared to the traditional farming The lowest yields were measured in 1988 (65 31%) and 1985 (66 67%) on the graded fanya juu and on the graded bund respectively The mean annual yield was 109% on grass strips, 138.3% on graded fanya juu and 106.9% on graded bund compared to the traditional farming which was taken as having 100 percent (Table 20).

Table 20 Crop yield of the experimental plot I

Year	Crop type	Traditional farming		Graded bund		Graded fanya juu		Grass strip	
		t/ha	index %	t/ha	index %	t/ha	index %	t/ha	index %
1984	Wheat	0.87	100	0.80	91.95	0.84	96.55		
1985	Barley	0.18	100	0.12	66.67	0.14	77.78		
1986	Wheat	0.92	100	0.74	80.43	1.03	111.96		
1987	Barley	0.01	100	0.03	300	0.04	400.00		
1988	Wheat	0.49	100	0.33	67.35	0.32	65.31		
1989	Niger Seed	0.06	100	0.04	66.67	0.07	116.67	0.08	133.33
1990	Field Peas	0.04	100	0.03	75.00	0.04	100	0.04	100
1992	Wheat	0.16	100	0	0	0	0	0.15	93.75

In EP II, the highest yield was measured in 1989 (183%) and the lowest in 1990 (42.3%) on the graded grass strips. On the graded fanya juu, the highest yield was measured in 1984 (143.06%) and in 1990 (147.62%). The lowest yield on graded fanya juu was measured in 1987 (67.35%). In 1984 and 1985, no yield difference was observed between graded bund and traditional farming. On the following years, however, lower yield was measured on the graded bund while the highest yield was measured in 1989 (102.9%) compared to the traditional farming. The mean annual yield was higher in the graded fanya juu (111.8%) and the grass strips (112.7%). The lowest yield (92.2%) was measured on the graded bund compared to the traditional farming which was taken as having 100 % (Table 21).

Table 21 Crop yield of the experimental plot II

Year	Crop Type	Traditional farming		Graded bund		Graded fanya juu		Grass strip	
		t/ha	index %	t/ha	index %	t/ha	index %	t/ha	index %
1984	Horse B	0.72	100	0.72	100	1.03	143.06		
1985	Teff	0.08	100	0.08	100	0.06	75		
1986	Horse B.	0.33	100	0.27	81.82	0.33	100		
1987	Teff	0.49	100	0.43	87.76	0.33	67.35		
1988	Horse B.	0.26	100	0.24	92.31	0.34	130.77		
1989	Barley	0.35	100	0.36	102.9	0.43	119.4	0.64	183
1990	Horse B.	0.26	100	0.21	80.77	0.31	147.62	0.11	42.3
1992*		-	-	-	-	-	-	0.32	-

* No data, except grass strip

Statistical analysis indicated that there was no significant difference on crop yield among treatments at 1 % level of significance (Appendix 6).

4.1.13 Influence of soil erosion on crop yield

Table 22 shows the correlation between soil loss and crop yield on the two sites. The highest correlation on soil loss and crop yield (r = 0.92) was observed on grass strip while, the lower correlation (r = 0.44) was observed on traditional farming in EP I. In EP II the correlation between soil loss and crop yield was very low compared to EP I. The highest (r = 0.33) and low (r = 0.17) correlations were observed on traditional farming and grass strip respectively The influence of soil loss on crop yield was not clear on EP I. However, there was a strong relationships between soil loss and crop yield in EP II. That is crop yield declined linearly with increases in soil loss

Table 22 Relation between soil loss and crop yield

	Treatments	Regression Equation	Correlation coefficient (r)
EP I	Traditional farming	$y = 0.0046x - 0.2193$	0.44
	Graded bund	$y = 0.0063x - 0.0555$	0.81
	Graded fanya juu	$y = 0.0069x - 0.0096$	0.65
	Grass strip	$y = 0.0019x - 0.0324$	0.92
EP II	Traditional farming	$y = -0.0009x - 0.4437$	0.33
	Graded bund	$y = -0.0008x + 0.3717$	0.20
	Graded fanya juu	$y = -0.0019x + 0.5051$	0.32
	Grass strip	$y = -0.0016x + 0.413$	0.17

y is crop yield (t/ha); x is soil loss (t/ha)

4.1.14 Crop rotation of the Anjeni area

Crops grown in EP I was wheat, barley, niger seed and field peas. In EP II crops grown were horse bean, teff and barley. The types of crop and period of rotation were based on types of soil and slope of the area. The crop rotation cycles and the variety of crops shown in figure 17 were typical for Anjeni area

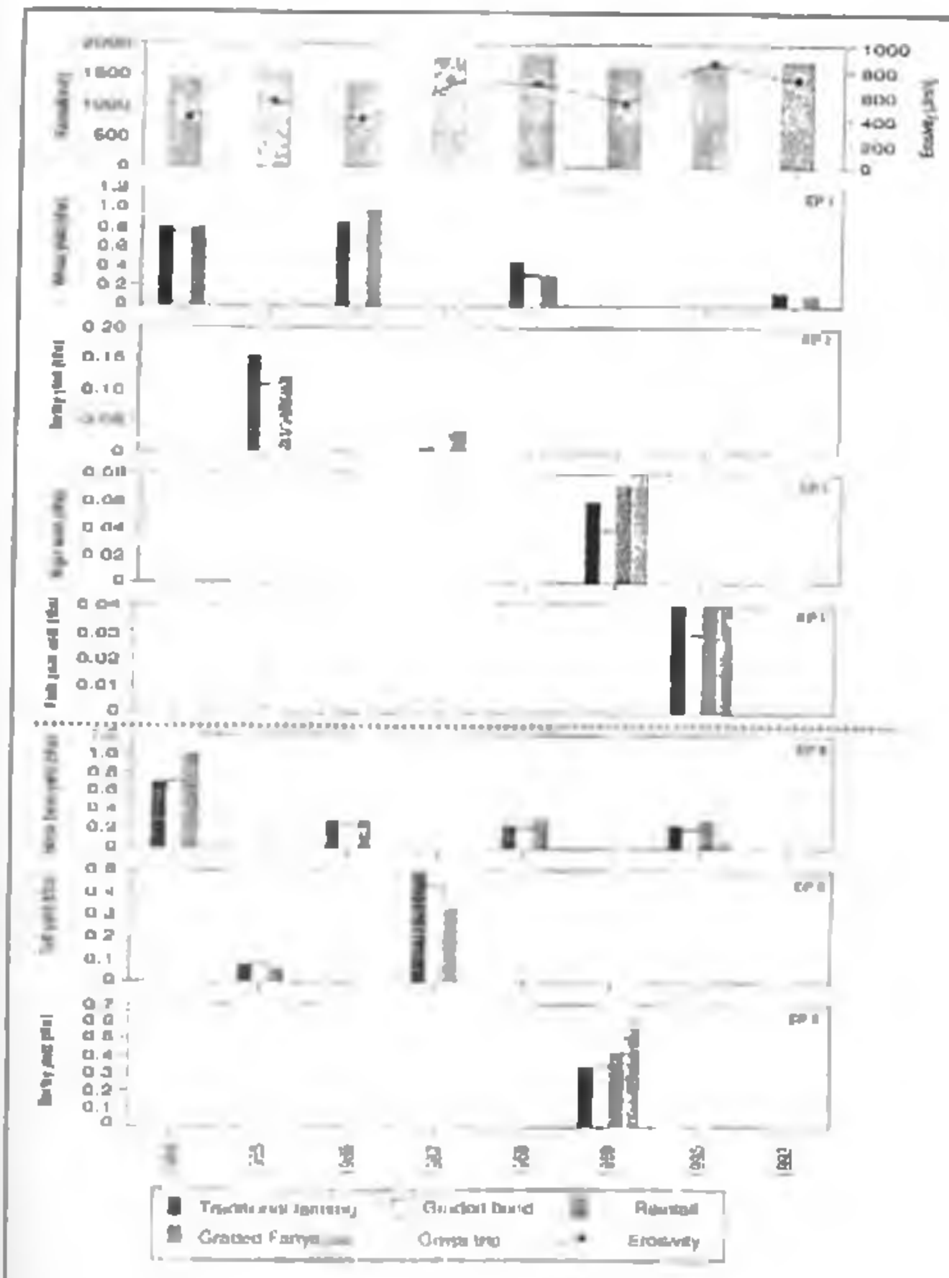


Figure 17 Annual rainfall, erosivity, crop rotation and crop yield of the experimental plots

4.2 Results on the status of soil and water conservation in the Gojam Highlands

4.2.1 Dominant soil and water conservation measures in the Gojam Highlands

The questionnaire revealed that traditional ditches and/or a combination of bunds with traditional ditches are dominant in the Wurch (above 3200 m asl) and the Dega (2300-3200 m asl) zones Soil and water conservation measures carried out in these zones showed that 40 % were traditional ditches and 60 % were a combination of bunds with traditional ditches In the Weyna Dega (1500-2300 m asl) zone the main soil and water conservation method was traditional ditches (99%) and only a small percentage (1%) consisted of a combination of bunds with traditional ditches which was practised on the transition zones. Unlike the other agro-climatic zones, the Kolla (below 1500 m asl) zone was mainly having bunds (Table 23).

Table 23 Percent coverage of soil and water conservation methods in different agro-climatic zones

Traditional agro-climatic zone	Conserved cultivated land (%)	Methods for soil and water conservation (respondent farmers in percent)		
		Traditional ditches	Bunds	Combination of bunds with traditional ditches
Wurch	100	40	-	60
Dega	100	40	-	60
Weyna Dega	100	99	-	1
Kolla	100	-	100	-

Twenty six soil and water conservation measures were identified during an inventory made by Soil Conservation Research Project (Kruger et al, 1995) in the highlands of Ethiopia. The seven most widely spread and frequently used techniques in Gojam highlands are graded stone bund, level stone bund, graded soil bund, level bund, grass strip, traditional ditches and agroforestry (Table 24).

Table 24 Types of soil and water conservation measures (%) in different agro-climatic zones of Gojam highlands

Traditional agro-climatic zone	Soil and water conservation measures (%)						
	Graded stone bund	Level stone bund	Graded soil bund	Level soil bund	Grass strip	Traditional ditches	Agroforestry
Wurch	24	-	85	-	1	100	-
Dega	20	-	80	-	-	100	-
Weyna Dega	-	-	1	-	0.1	98.9	-
Kolla	-	80	-	10	-	-	10

In the Wurch zone, 85 and 24% of the physical structures were found to be graded soil bund and graded stone bund respectively. Traditional ditches cover almost all the cultivated lands in this zone (i.e., 40 and 60% of the cultivated land is covered with traditional ditches and traditional ditches combined with bunds respectively). In the Dega zone, 80 and 20% of the physical structures consisted of graded soil bund and graded stone bund respectively. At the time of the survey, no physical structure had been used in the Weyna Dega zone, except at the upper reach and the lower escarpment of the zone (with 1.1% physical structure). Almost all cultivated land in the Weyna Dega had traditional ditches. The Kolla zone had 80, 10 and 10% level stone bund, level soil bund and agroforestry respectively (Table 24 & Figure 18).

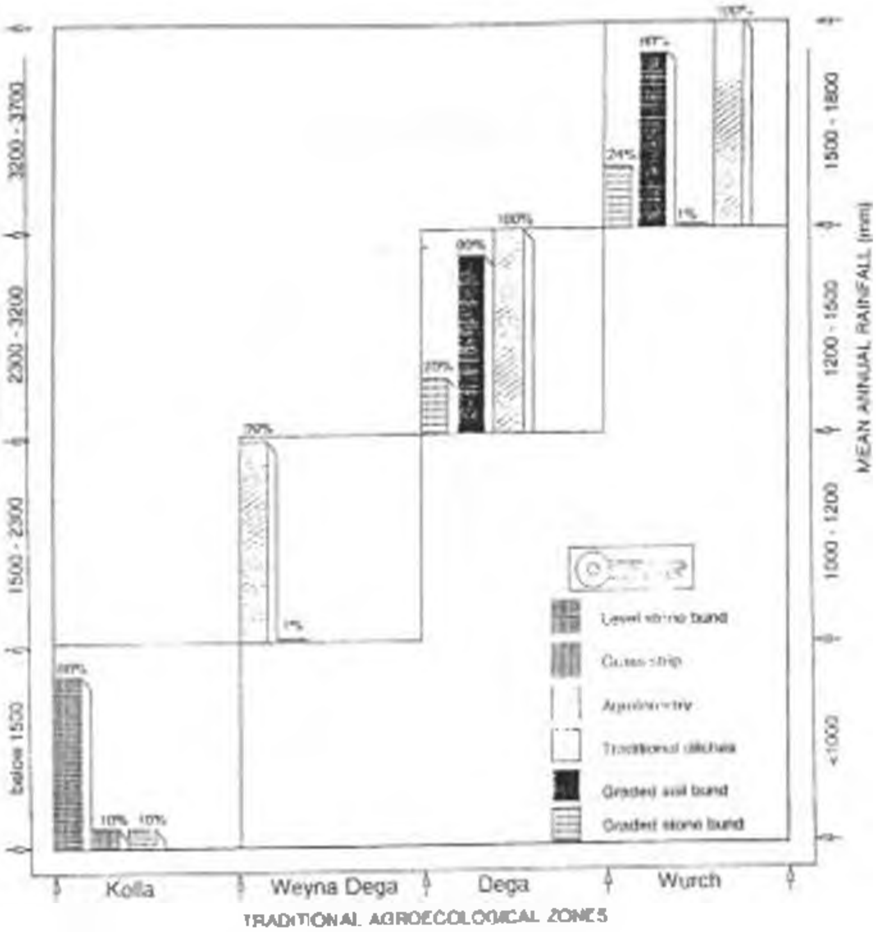


Figure 18 Distribution of common soil and water conservation measures in different agro-climatic zones of Gojam highlands

4.2.2 Farmers' perception on the effect of soil and water conservation measures

The farmers were asked whether the output (crop yield) from the soil and water conservation was high, low or not known and about other benefits obtained from soil and water conservation measures and the problems associated with soil and water conservation practices In Wurch zone, 30 % of the respondents said that the output was high, while 10 percent of the respondents indicated that the output was low Sixty percent of the respondent answered the output of soil and water conservation measures were insignificant However, in the Dega zone, 50 % of the respondents indicated high while 40 % of them answered that the output of the soil and water conservation measure was insignificant. The questionnaire revealed that the output of traditional ditches was high in Weyna *Dega* zone (100%). In Kolla zone, the output of soil and water conservation practice was high (90 %), and only 10 % of the respondents indicated that the output was insignificant.

Table 25 Advantage and disadvantage of soil and water conservation measures in different agro-climatic zones (respondent farmers in percent)

Traditional agro-climatic zone	output (%)			Other benefits	Constraints
	High	Low	Insignificant		
Wurch	30	10	60	Grazing on the bunds (20%)	-Narrow spacing between bunds -Reduce farm size -Pest infestation -Waterlogging
Dega	50	10	40	Grazing on the bunds (10%)	-Narrow spacing between bunds -Reduce farm size -Pest infestation -Waterlogging
Weyna Dega	100	0	—	-	-Not sufficient during high storms
Kolla	90	-	10	Grazing on the bunds (30%)	-Labor intensive during construction

The main constraints associated with soil and water conservation structures in Wurch and Dega zones were narrow spacing between bunds, reduction of farm size, pest harbouring and waterlogging behind the bunds (Table 25). In the Weyna Dega zone traditional ditches alone were not sufficient to drain the excess water to the waterways during heavy storms. Failure to drain excess water can cause down slope damage. In Kolla zones, however, the main constraint was shortage of labour during construction of stone bunds. All farmers at each agro-climatic zone were equally affected by the constraints associated with soil and water conservation measures

5 DISCUSSION

5.1 Land use change in Anjeni area

Cultivated land showed an increasing trend since 1984 Whereas other land uses such as grassland decreased from 38% in 1984 to 18% in 1992. In Anjeni area bush land and grassland including steep slopes were under cultivation, to feed the ever increasing population of the area. Fallow periods were decreasing and lands under fallow decling with time due to population pressure The trend indicates that there was a higher demand of cultivated land compared to other land uses in the catchment. The result further indicated the urgent needs of environmentally sound, socially accepted and economically viable soil and water conservation measures in order to reduce soil loss from cultivated land and increase productivity per unit area

5.2 Effects of individual storms on soil loss

Soil losses from experimental plots are a function of different factors. First, the quantity of rainfall which causes erosion (detachment and transporting sediment); secondly, ground covers, that intercept the energy and increase infiltration, and consequently reduce soil loss; and thirdly the topographic position of the site. Therefore much of the annual soil loss occurred as the result of a single or few storms that coincide with bare land during and after the onset of rain More than 50% of the annual soil losses occurred during less than 10 storm events which account for less than 20% of the annual storm events (28% of the mean annual rainfall was in July)

In spite of the lower percentage of the annual rainfall and energy, the mean soil loss was higher in July, when the land was under seed bed preparation, especially teff field that is sown in August It is evident that lower or absence of ground cover resulted in a higher soil loss in July. However, as the ground cover increased, even the higher rainfall events with higher energy did not produce significantly higher soil loss But teff planted in August and it can only attain full land cover around the end of erosive rainfall (in September).

The vegetation cover result measured on test plots in 1988 for two crops showed that wheat on test plot I (28% slope) attained about 75% ground cover at the end of September. On test plot II (12% slope), beans attained about 70% ground cover at the beginning of September On both cases, however, the effective ground cover to reduce soil loss was attained at the end of erosive rainfall. Therefore, a large portion of the arable land in Anjeni area remains bare during erosive rainfall The small seed, teff is normally planted at the end of the big rain in order to avoid seed wash. In general the farming system of the Anjeni area was not conservation based and therefore the need for soil conservation measures are urgent for such an area.

5.3 Runoff and soil loss relationships

The correlation between runoff and soil loss was high at both experimental plots (EP I and EP II). The low correlation (r – 0.56) on the graded fanya juu (EP I) implies that greater runoff did not result in greater soil loss on that plot compared to the other plots This indicated that graded fanya juu trapped sediments behind the bund and allowed the excess water to drain through the ditches below the bund, a function that it is normally expected to perform as a soil conservation measure

Higher correlation was observed on the grass strip on both sites, compared to the other plots (r = 0.95 and r = 99 on EP I and EP II respectively) This implies that higher runoff result in higher soil loss on that plot. This indicates that grass strip was not effective in reducing soil loss at its early stage of development (3 years old) in higher rainfall areas

5.4 Mean monthly and annual runoff and soil loss variation

The highest mean monthly runoff and soil loss was observed in June, July, August and September on both sites. This was mainly due to the higher erosive rainfall distribution in these months The annual runoff and soil loss showed a similar trend on both sites, treated with different soil conservation measures The lowest runoff and soil loss was measured at both sites in 1988 and 1989 due to the lower erosivity (675.3 and 531.1 Jm-1h-1 in 1988 and 1989 respectively). In 1987 and 1990, however, the highest runoff and soil loss was observed due to the higher erosivity (731.2 and 874.3 J/mh in 1987 and 1990 respectively). Therefore the result showed that there was a clear correlation between runoff/soil loss and erosivity. No clear correlation was observed between runoff /soil loss and rainfall amount at both sites.

The other possible reason why soil loss and runoff so high in these period was the fact that during these months land was under seed bed preparation and bare. Teff is the dominant cultivated crop in Anjeni area. According to the practices of the farmer, teff fields are ploughed repeatedly (3-5 times) and the surface may be clean, smooth and pulverized before it is sown. Ploughing was a continuous process, which was done after the soil had been moistened by showers and it was repeated several times before sowing. The reason for repeated ploughing has been given for Anjeni area (Berhanu, 1991).

> " *The essence of ploughing was to pulverize the soil, to control weeds and to some extent minimize the danger of insects and diseases on the newly growing crops.*"

The fine soil particles, the smoothness of the field and the lack of vegetation cover in an area of such high rainfall increase the high risk of erosion.

The document further pointed out that on gentle slopes and on future terraces, it would be indispensable to introduce biological measures in combination with physical measures to achieve quicker results. Physical conservation measures must be seen as part of an integrated conservation strategy.

5.5 Technical efficiency of soil and water conservation measures

Graded fanya juu showed lower soil loss compared to graded bund although both have spillways of the same length and width. The ditches of the graded bund are situated up slope or above the bund which directly drain the eroded materials from the cultivated land up slope to the spillways. In case of graded fanya juu, however, the ditches are situated below the bund in which the eroded materials from up slope are trapped by the fanya juu bund before it reaches to the collection ditches below the fanya juu bunds and then drain to the spillways This means that all runoff from the ditches of the graded bund enter the collection tank, resulting in higher annual soil loss and runoff than the graded fanya juu.

The grass strip and graded bund had similar annual soil loss results in both sites while graded fanya juu had annual soil loss results which are lower than those of the grass strip and graded bund. This happened partly because of the micro-topographic situation. The ditches of graded fanya juu situated below the bund trapped a big portion of the sediment before it reached the collection tanks through the spillways. On grass strips, however, the eroded sediment drained directly or via spillways into the collection tanks This means that the sediment was readily draining into the collection tanks as opposed to that of the graded fanya juu, which tended to remain behind bund and /or silted up in the ditch below the fanya juu bund. Sediment loaded water can only drain into the fanya juu ditches and then into the spillways if the level behind the bund is raised above the level of the fanya juu bund and the ditches below the bund silted up, a condition which can only happen due to improper maintenance

Soil conservation structures that allow faster development of terraces are highly valued in any soil conservation effort Belay (1992), pointed out that bank height is increasing tremendously and the inter-structural slope considerably reduces from the very beginning of the construction of fanya juu bunds. In addition, Thomas (1984), pointed out that throwing soil uphill to make terrace reduces the slope, which itself makes a major contribution to reducing soil loss on steep land, while throwing downhill, as in bunds to form a ridge, increasing the slope

5.6 Effect of soil and water conservation measures on soil loss

The average annual soil loss results from experimental plots (average of the means of graded bund, graded fanya juu and grass strip) shown in the result section (48 3 and 36 5 t/ha/yr on EP I and EP II respectively) have no much difference with the average soil loss rate (42 t/ha/yr) for untreated cultivated land of the Ethiopian Highlands estimated by Hurni (1985). Therefore the effectiveness of the soil conservation measures to reduce soil loss is much lower than the average soil loss formation rates (5 to 11 t/ha/year) for cultivated land in the highlands of Ethiopia as estimated by Hurni. However, such crude estimation may cause confusion and may be thus misleading. The average annual soil loss obtained from control plots were 109.2 and 88.16 t/ha/yr from the steeper and gentle slopes respectively, which were much higher than the average soil loss rate estimated by Hurni.

Similar studies in different parts of the country have shown variations and similarities on soil loss reduction under the same soil conservation measures. Southern Ethiopia (Gununo) with 14% gradient and 1345 mm mean annual rainfall on a Humic Nitosol, the average annual soil loss from conservation structures was 0.5 t/ha/yr far much lower than obtained from Anjeni In Central Highlands of Ethiopia (North Shewa), with slope of 24% and mean annual rainfall 1213 45 mm the soil loss was 40 t/ha/year similar to the Anjeni one. (source: SCRP data base).

The similarity between Central Highlands and Anjeni area is due to the practicing of erosion induced farming system such as pulverizing and smoothening of cultivated land before planting that makes the soil vulnerable to erosion. In the Southern Ethiopia repeat ploughing is not common and the land remains covered until the planting time.

5.7 Effects of soil and water conservation measures on yield

Physical soil conservation structures showed complete success in terms of reducing soil loss compared to the traditional farming It was observed that graded fanya juu and graded bund reduced soil loss by 54 and 52.5% respectively compared to the traditional farming on steep slopes On a gentle slope soil loss reduced by 67 and 32 % on graded fanya juu and graded bund respectively compared to the traditional farming However, there were no increases in yield. This may be due to the fertility of the soil, which is uniformly distributed throughout the effective rooting depth such that soil loss may not adversely affect the soil fertility with depth. Farmers interviewed indicated that the lower yields on physically conserved fields were as the result of improper maintenance of soil and water conservation measures due to shortage of labour during peak periods causing waterlogging above the bund, which affects seeds germination. Other farmers indicated that physical structures do harbor pests that affect the crop yield. Views from extension agent revealed that the primary aims of physical soil conservation structures are to reduce soil loss and consequently increase soil productivity and in the final analysis, agricultural yields.

Ludi (1997) has given similar reasons. Of the 23 households interviewed, 19 stated that mice were a severe problem in conservation structures mainly in soil bunds and caused a reduction in crop yields. Other factors mentioned as having an effect on crop yields included stagnant water (9 households), weeds (5 households), birds (2 households), and competition between grass on the bunds and crops in the fields (2 households).

Average grain yields were calculated (Belay, 1992) in southern Ethiopia for a period of 1985-1989 on grass strip (0.598 t/ha), graded fanya juu (0.595 t/ha) and graded bund (0.568 t/ha). Compared to the control plot (0.593 t/ha), grass strip and graded fanya juu showed neither declines nor increments, while on graded bunds reduction of 4% was registered.

Another evidence has been given by Mulugeta (1988). If the yields calculated without reducing the area taken by the soil conservation structures are considered, it was observed that the control plot showed higher yields than the other experimental plots. This was most likely due to the fact that the control plot had more area under crops than the other experimental plots (the area taken by the conservation measures on the treated plots ranged from 14 to 20% of their total areas).

The decline in yield on the treatments through time cannot be explained in terms

The decline in yield on the treatments through time cannot be explained in terms of rainfall. The rainfall amount and distribution between 1984 and 1992 was relatively better and uniform for Anjeni area (Figure 17).

To get good returns from soil and water conservation efforts, farmers' knowledge should be considered. A good example is in Kenya where soil and water conservation began by taking into consideration farmers problems, their needs, and existing conservation methods and involving them in local and regional projects with the aim of improving and perfecting them. The end result was a set of measures that farmers could and would carryout themselves, with their own resources and modicum of expert help. In Ethiopia, however, soil and water conservation effort was mainly to reduce soil loss using labour intensive earth work without giving consideration for locally proved farming practices.

5.8 Soil and water conservation techniques practiced in Gojam highlands

This study revealed that although the Government and NGOs pumped huge sums of money and involved millions of peasant man-days in the 1970s and 1980s for soil and water conservation activities (section 1, in this paper), the farmers reverted to their traditional systems as soon as the food for work and imposed campaign work were discontinued. The cause of failure was due to application of single technology for different agro-climatic zones, lack of appreciation of indigenous knowledge and top- down approach.

On the higher altitudes (above 1500 m asl), all farmers used traditional ditches on their cultivated land, irrespective of whether or not other forms of soil and water conservation measures existed. Older farmers mentioned that they had been using traditional ditches for a long time and that many of them were inherited. For this reason, there were a lot of local farmers' sayings on traditional ditches.

Arso Yalefesses Temwagto Yalewass (from West Gojam zone), 'One can not imagine ploughing without traditional ditches as irrigation without bail is unthinkable' and Kezera Gebere Yahoyew Yibelthal (from North Shewa zone) 'a framer who made traditional ditches is by far better than one who sowed'

These sayings indicate the historical importance of ditches within traditional farming practices (Million, 1996).

There are indeed farmers' technical methods of dealing with almost all the land degradation problems in the Ethiopian highlands (section 2.5). Many of them require relatively little capital and expertise. Moreover, the selection of soil and water conservation measures for a given agro-climatic zone is based on the availability of construction materials, purpose of the structures, prevailing environmental conditions (rainfall, slope, soil type) and the farming systems. In the high rainfall areas, graded structures and traditional ditches are common, because of the need to drain excess water safely from the cultivated land. On such high rainfall area soil and water conservation structures can serve the purpose only when combined with traditional ditches. In the highlands of Gojam, where there is long rainfall period and intensive rainfall, the purposes of soil and water conservation measures are to drain excess water safely to the natural or artifical waterways. However, due to lack of proper maintenance and weak lay out, retention and accumulation of water (water logging) behind the bund has been observed.

5.9 Impact of soil and water conservation measures in Gojam highlands

The main purpose of soil and water conservation measures are to protect the soil and the seed (especially small seeds like teff) from being washed away by surface runoff in Wurch Dega and Weyna Dega zones. In the Kolla zone, the purposes of soil and water conservation measures are to retain water and soil behind the bunds, to increase the moisture content of the soil and improve the fertility status of the soil.

The effectiveness of the soil and water conservation measures to drain excess water or to retain water and conserve soil varies from one zone to the other. Graded soil bund, traditional ditches and cutoff drains were more effective in draining excess water and in conserving the soil in Wurch and Dega zones. Traditional ditches were used to drain excess water from cultivated lands in the Weyna Dega zone. Level bunds were more effective in conserving soil and water in the Kolla zone (Table 26).

Table 26 Major soil and water conservation measures and their function in different agro-climatic zones of the Gojam highlands

Traditional Agro-climatic zone	Soil and water conservation techniques practiced in each agro-climatic zone		Function	Effective Soil and water conservation measures as suggested by the farmers
	Traditional	Improved		
Wurch	-Traditional ditches -Cutoff drain -Waterways -Crop rotation	-Graded stone bund -Graded soil bund -Waterways -Crop rotation	-To protect the soil and seed from being washed away by run on -To drain excess water from cultivated fields	Graded soil bund and traditional ditches
Dega	-Traditional ditches -Cutoff drain -Water ways -Crop rotation -Fallow	-Graded stone bund -Graded soil bund -Water ways -Cutoff drain	-To protect the soil and seed from being washed away by run on -To drain excess water from cultivated fields -To improve soil fertility	Graded soil bund, traditional ditches and cutoff drain
Weyna Dega	-Traditional ditches	Cutoff drain	-To drain excess water mainly from cultivated land	Traditional ditches and cutoff drain
Kolla	-Stone bund -Grass strip -Agroforestry	Level stone bund	-To conserve soil and water in situ -Improve soil fertility	Level stone bund

5.10 Problems and limitations for the adoption of soil and water conservation measures in the Gojam highlands

The questionnaire survey further revealed that in spite of the positive impact of soil and water conservation on yield and environment, there were some constraints during and after implementation of soil and water conservation measures. The newly introduced approach for soil and water conservation measures were constructed based on a generalized guideline of using vertical interval of 1 meter One meter vertical interval in a steep land reduces the horizontal distance between bunds. The narrower spacing between bunds affects the use of yoked oxen during ploughing. Also the higher the number of bunds for a given area, the less the size of the farm which can be used for planting crops.

Moreover, the main problem that was frequently mentioned by the land users was waterlogging due to the retention of excess water behind the bunds in the high rainfall areas and harbouring of pests under soil and water conservation structures. During high storms, traditional ditches alone are not sufficient to drain excess water into the natural/artificial waterways Traditional ditches could lead to over topping during high storms leading to down slope damage and siltation. Some soil and water conservation measures (for example stone bund) required high labour input during construction, which is difficult to afford by subsistence farming However, at the lower altitude most of the cultivated fields were terraced.

No technical or social problem was associated with the laying out of the level bunds on lower altitude where the rainfall is generally low Most of the work that was done in the 1970s and early 1980s could still be seen in the lower altitude areas Apart from the campaign work that was done earlier, farmers continue to construct new bunds and maintain the old ones with or with no assistance from the technical staff Technical as well as social problems are prevalent when applying graded and/or level bunds on the middle and higher altitudes The farmers showed interest to continue with their own techniques and therefore they were reluctant to accept the newly introduced measures. The slow adoption of the improved techniques was due to the fact that in most cases the techniques (physical structures) were not fitting well with the existing farming systems and socio-cultural conditions of the highlands (unable to use yoked oxen, waterlogging, high cost of construction, etc).

In the 1970s and early 1980s the approaches were top-down, which was not involving the farmers in the processes of soil and water conservation implementation. Thus no information was given on the purpose and outcome of soil and water conservation techniques to the user

Shortage of trained manpower was identified as one of the problem, which hinders the adoption of soil and water conservation techniques. One development agent serves for 600-800 farmers which is a high number to manage during peak seasons. Moreover, due to unseen circumstances (death, transfer, etc of the DAs) services may discontinue for some peasant associations for one or more years.

The new constitution of the country says that land will remain in the hands of the state and the public. Absence of land ownership and proper land use policies are the major reasons for lack of investment in land improvement and construction of high labour input earth works. This argument which is associated with the frequent redistribution of land can highly influence the long-term investment and therefore makes the peasants reluctant to invest highly in their farms

5.11 Prospects of soil and water conservation in Gojam highlands

Sustainable soil and water conservation technology accommodates and entertains the prevailing environmental conditions and the well being of the user. Therefore selection of appropriate soil and water conservation technology with the participation of the targeted group enhances the sustainable use of the technology. During the study period, the author observed community based soils and water conservation activities in the Gojam Highlands. As far as the approaches are concerned, there are signs of improvement for soil and water conservation implementation. The main change along this line is the participation of farmers in the processes of soil and water conservation implementation, appreciation of indigenous knowledge and flexibility of the technologies.

The recent enhancement of the farmers' participation in identifying their problem, prioritization, planning and implementation in the highlands signifies the realization of the weaknesses associated with the top-down approaches. Although the bottom-up approach is reported to be successful, it remains to be seen if it can be sustainable. The complaints of farmers over narrow spacing between bunds due to fixed vertical interval (1 meter) can be modified according to the local farming system and socio-cultural practices. To minimize the technical problems (such as narrow spacing between bunds, reduction of farm size, etc.,), bunds are removed alternatively and combined with farmers own techniques (traditional ditches)

6 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The runoff and soil loss results that are presented in this study are an indicator of the danger of soil losses in the Ethiopian highlands. Moreover, most of soil losses occur at the onset of rainfall. The high soil loss occurring when the land is bare showed that adequate land cover is important to reduce soil loss below the tolerance level for the Anjeni area which is estimated to be between 10 and 15 t/ha/y (Werner, 1986).

Although the observed runoff and soil losses were very high under different soil and water conservation measures, still statistical differences existed between techniques. The results indicate that physical structures have low soil losses compared to the traditional farming (control). The statistical analysis further suggested that apart from other socio-economical problems, grass strip, graded fanya juu and graded bunds are equally effective in reducing runoff and soil losses on steeper slopes. However, on gentle slopes graded fanya juu was more effective in reducing runoff and soil loss for the highlands having topographic and climatic conditions similar to the Anjeni research unit.

An important observation that has been noticed during the questionnaire survey was that the selection of soil and water conservation measures for a given locality is based on its function and availability of construction materials. Level stone bunds, for example, are frequently used at the lower altitude for soil and water conservation, while traditional ditches and graded bund are used at the higher altitude where their function is to drain excess water safely out of the field.

The constraint for the adoption of sustainable soil and water conservation measure that has been noticed during the questionnaire survey was absence of land ownership and land use planning. Due to absence of clear land tenure system (the existing system is such that land remains in the hands of the state and the public), farmers cultivate the land under temporary arrangements and expect land to be taken away from them during the next land redistribution. Under these conditions, peasants may perceive investment in a long-term land improvement (construction of high labour input terrace and planting trees) as inappropriate because they are unlikely to reap the benefits of their work. Therefore farmers prefer least or no investment technologies such as traditional ditches which is, in most cases, less effective in reducing soil losses.

Lessons learned from past mistakes revealed that, there is no need to import all technologies. Instead intermarriage of exotic with native technologies may be socially accepted, economically viable and ecologically sound

6.2 Recommendations

1. The results obtained from the experiments can help in improving the selection and design of soil conservation measures. Therefore demonstration and dissemination of the effective soil conservation measure(s) have a vital role for the sustainable use of soil and water conservation measures in the Gojam highlands

2. Involving farmers as a co-researcher at all levels of research process (planning, implementation, etc.) can facilitate the dissemination of effective soil and water conservation measures and sustainable use of it.

3. The most erosive and the highest soil loss periods are the months of June, July and August. During this period the entire catchment is under seed bed preparation and bare. During these months, physical soil conservation measures alone are not sufficient to reduce the energy of erosive rainfall. They have to be supplemented by protective cover at the onset of rain.

4. Physical soil conservation measures are suitable especially on steeper slopes to reduce soil loss. However, the productivity of the land due to soil conservation measures are

insignificant compared to the untreated area. A sustainable result may be achieved with a longer time frame of 10-25 years. To achieve quicker and attractive results, research aimed at increasing productivity such as intermarriage of physical with agronomic or biological soil conservation measures will be indispensable.

5. Soil loss rates on the conservation structures were well above the tolerance level that can occur in this area (10-15 t/ha/yr). Therefore soil conservation research in this area should be continued until more effective soil and water conservation measure has been obtained

6. Lack of long-term tenure dissuades farmers from investing where returns are not assured. In many cases, if tenurial rights cannot be granted to the satisfaction of the farmer, soil and water conservation efforts are unlikely to succeed. Moreover, absence of legislation on how to use natural resources in general and land in particular, leads to over-exploitation of the resources. Therefore formulation of policies on land ownership right and land use can minimize impacts of erosion on the environment.

7. Application of a single measure from the foot of mountains to the top of it is dangerous. A pilot project study, to test technical feasibility is indispensable for sustainable use of soil and water conservation techniques before large-scale implementation. Furthermore, a study on how to combine new approaches of soil conservation and indigenous knowledge is required in order to identify suitable soil and water conservation measures. In planning, catchment approach is essential to ensure the soil and water conservation effort is effectively utilized. If farms on a long steep slope are divided into many small individual fields, close co-operation between farmers is required to ensure that conservation measures carried out on up slope fields does not damage fields below
8. Supporting the farmer by providing extension service, hand tools and wherever necessary, credit etc. can enhance soil and water conservation efforts. To supply the necessary services for proper implementation and maintenance of soil and water conservation measures, adequate guidelines and trained manpower is needed

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8 APPENDICES

Appendix 1 Evaluation of the rainfall data as used by SCRP

Time	N	I	Y	E			
					E*	I_{30}	R
	a						b =

Explanation

Time : Time in minutes when rainfall is occurring (uniform intensity interval)
N : Amount of rainfall in the interval (in centimetres)
I : Intensity of rain in the interval, in cm per hour
Y : Energy of one cm of rain in the interval: $Y = 210 + 89 \log I$ (in Joules m^{-2})
E : Energy of rain in interval: $E = NY$ (Joules m^{-2})
I_{30} : Maximum 30-minute intensity of storm (whole period), in cm per hour: cm h^{-1}
E* : Energy of storm: E* = Sum of all E added together (J m^{-2})
R : Erosivity of storm: $R = 10^{-3} EI_{30}$, if $a > 1.25$ cm, otherwise $R = 0$ (10^{-3} $Jm^{-2}h^{-1}$)
a : Total amount of rainfall in the storm. Sum of all N (cm)
b : (= R) Erosivity of the storm

Appendix 2 Monthly rainfall, erosivity, runoff and soil loss on EPs

1984

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall						11	141	360	370	266	189	24	46	
Erosivity							47	138	177	32	22			
EPI	Runoff	Traditional farming					42	132	139	127	67	3		
		Graded bund					41	121	127	136	80	3		
		Graded fanya juu					30	127	113	137	92	2		
	Soil loss	Traditional farming					14	36	81	21	9	1		
		Graded bund					13	34	72	19	8			
		Graded fanya juu					13	37	57	20	10			
EP II	Runoff	Traditional farming					37	114	120	110	60			
		Graded bund					33	95	100	108	63	2		
		Graded fanya juu					31	57	111	110	61	2		
	Soil loss	Control					5	12	27	7	3			
		Graded bund					5	12	25	7	3			
		Graded fanya juup					5	13	25	10	3			

1985

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall			3	2	14	72	135	234	380	333	265	77	21	22
Erosivity						24	20	123	130	149	90	17		
EPI	Runoff	Traditional farming				12	40	137	113	130	98	3		
		Graded bund				9	36	123	103	118	78	2		
		Graded fanya juu				7	18	106	95	115	77	2		
	Soil loss	Traditional farming				3	6	27	42	15	6			
		Graded bund				2	4	16	26	9	4			
		Graded fanya juup				2	3	15	23	8	4			
EP II	Runoff	Traditional farming				17	29	145	153	139	75			
		Graded bund				14	24	112	117	126	74	3		
		Graded fanya juu				11	21	57	111	110	61	2		
	Soil loss	Control				4	13	42	95	25	10			
		Graded bund				4	9	34	71	19	8			
		Graded fanya juu				2	4	15	28	11	3			

1986

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall				7	34	11	57	270	336	295	211	115	31	7
Erosivity					6		56	44	67	99	58	52	11	
EPI	Runoff	Traditional farming					2	51	120	141	106	50		
		Graded bund					3	42	78	72	92	51		
		Graded fanya juu					2	29	86	74	80	49		
	Soil loss	Traditional farming					2	41	52	27	12	3		
		Graded bund					8	26	20	7	6	2		
		Graded fanya juu					3	20	21	6	4	1		
EP II	Runoff	Traditional farming					8	117	54	107	100	57		
		Graded bund					7	69	36	85	68	41		
		Graded fanya juu					9	54	23	55	43	26		
	Soil loss	Control					13	34	8	8	3			
		Graded bund					9	25	5	4	2			
		Graded fanya juu					3	9	1	1				

1987

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall			6	33	75	51	191	328	405	383	183	100	19	38
Erosivity				17	21	23	64	136	197	195	35	34		8
EPI	Runoff	Traditional farming				1	8	82	223	251	51	4		
		Graded bund					4	68	149	242	51	3		
		Graded fanya juu					1	38	160	211	47	4		
	Soil loss	Traditional farming					1	60	43	32	2			
		Graded bund						19	12	12	2			
		Graded fanya juu						10	15	12	2			
EP II	Runoff	Traditional farming				1	19	147	74	298	90	17		
		Graded bund					14	98	54	224	76	12		
		Graded fanya juu					2	45	29	145	56	7		
	Soil loss	Control					8	25	23	97	15	1		
		Graded bund					4	13	7	60	6			
		Graded fanya juu						2	3	22	3			

1988

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall			37	44	5	6	72	310	580	350	213	211	16	10
Erosivity			5	10			6	133	238	111	64	106	4	
EPI	Runoff	Traditional farming						5	180	77	99	120	1	
		Graded bund						2	109	65	73	95		
		Graded fanya juu						2	102	53	56	68		
	Soil loss	Traditional farming							52	19	27	13		
		Graded bund							18	8	10	6		
		Graded fanya juu							16	7	8	5		
EP II	Runoff	Traditional farming						19	112	109	71	81		
		Graded bund						9	57	68	52	45		
		Graded fanya juu						8	64	42	31	28		
	Soil loss	Control						1	10	5				
		Graded bund							4	3				
		Graded fanya juu							4	1				

1989

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall				43	84	88	122	160	455	327	279	96	23	10
Erosivity					24	16	47	26	227	84	77	30		
EP I	Runoff	Traditional farming					2	1	113	121	113	1		7
		Graded bund					2	2	78	63	63	1		2
		Graded fanya juu					2	2	89	84	89	1		2
		Grass strip						2	79	73	65			1
	Soil loss	Traditional farming							36	14	9			
		Graded bund							13	3	3			
		Graded fanya juu						1	15	6	5			
		Grass strip							9	1	2			
EP II	Runoff	Traditional farming					2	5	218	89	42			8
		Graded bund					2	4	95	44	23			1
		Graded fanya juu					2	5	92	38	21			1
							6	53	133	81	107	54		1
	Soil loss	Control						2	22	1			2	
		Graded bund						1	6					
		Graded fanya juu						1	5					
		Grass strip						10	24	3	2			

1990

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall			75	13	29	34	91	183	402	460	313	34	31	3
Erosivity							105	62	217	343	61		3	
EP I	Runoff	Traditional farming	5.4				28	17	137	156	167			
		Graded bund	2				3	3	49	91	96			
		Graded fanya juu	2				3	3	63	104	115			
		Grass strip	1				3	3	46	89	121			
	Soil loss	Traditional farming					1	6	16	47	24			
		Graded bund							3	8	4			
		Graded fanya juu							4	13	7			
		Grass strip						2	8	7				
EP II	Runoff	Traditional farming	11			29	29	78	236	182				
		Graded bund	2			10	9	36	136	72				
		Graded fanya juu	2			18	20	51	170	108				
		Grass strip	2			1	20	117	216	194				
	Soil loss	Control					17	13	36	86	23			
		Graded bund					1	1	3	11	1			
		Graded fanya juu					1	3	6	18	2			
		Grass strip					2	8	5	39	7			

Appendix 3 Procedures of calculating ANOVA for unequal replications of the experimental plot runoff and soil loss

Treatment (EP I, Runoff)	r_i	ΣY_{ij}	Y_i (mean)	ΣY^2_{ij}	Y^2_i/r_i
Traditional farming	8	4010.7	501.34	2048641.47	2010714.3
Graded bund	8	2893.9	361.74	1092423.41	1046812.15
Graded fanya juu	8	2804	350.5	1046681.22	982802.00
Grass strip	3	825.92	275.31	235222.19	227370.27
Total	27	10534.52	1488.89	4422968.29	4267718.72

Treatment (EP I, Soil Loss)	r_i	ΣY_{ij}	Y_i [illegible]	ΣY^2_{ij}	Y^2_i/r_i
Traditional farming	8	976.8	122.1	128319.16	119267.28
Graded bund	8	465.9	58.24	38834.19	27132.85
Graded fanya juu	8	452.3	56.54	35505.13	25571.91
Grass strip	3	90.9	30.30	4206.89	2754.27
Total	27	1985.9	267.18	206865.37	174726.31

Treatment (EP II, Runoff)	r_i	ΣY_{ij}	Y_i (mean)	ΣY^2_{ij}	Y^2_i/r_i
Traditional farming	8	3612.0	451.5	1767073.44	1630818
Graded bund	8	2430	303.75	867846.04	1001112.5
Graded fanya juu	8	2109.04	263.63	623137.77	556006.22
Grass strip	3	1204.1	401.37	564858.91	483285.6
Total	27	9355.14	1420.25	3822916.38	3671222.32

Treatment (EP II, soil loss)	r_i	ΣY_{ij}	Y_i (mean)	ΣY^2_{ij}	Y^2_i/r_i
Traditional farming	8	705.28	88.16	72291.4	62181.01
Graded bund	8	381.2	47.65	34330.8	18545.38
Graded fanya juu	8	205.1	25.64	9059.71	5258.25
Grass strip	3	108.3	36.1	5659.77	3909.63
Total	27	1399.88	197.55	121341.68	89894.27

Where

Y_{ij} denotes the measurement in the ith treatment and jth year, where i = 1,2,3,4 and j = 1,2,3,...,8,
r = Number of replications (years) per treatment

Appendix 4 ANOVA table for runoff and soil loss

(EP I, Runoff)

Source of Variation	DF	Sum Square	Mean Sum Square	F*	1%
Among SCM (treatment)	3	157492.36	52497.45	7.8	4.76
Within SCM (error)	23	155249.57	6749.98		
Total	26				

(EP I, Soil Loss)

Source of Variation	DF	Sum Square	Mean Sum Square	F*	1%
Among SCM (treatment)	3	28659.69	9553.23	6.84	4.76
Within SCM (error)	23	32139.06	1397.35		
Total	26				

(EP II, Runoff)

Source of Variation	DF	Sum Square	Mean Sum Square	F*	1%
Among SCM (treatment)	3	146675.79	48891.93	7.18	4.76
Within SCM (error)	23	156694.06	6812.79		
Total	26				

(EP II, soil loss)

Source of Variation	DF	Sum Square	Mean Sum Square	F*	1%
Among SCM (treatment)	3	17314.12	5771.37	4.8	4.76
Within SCM (error)	23	31447.41	1209.53		
Total	26				

SCM: Soil Conservation Measures

Appendix 5 Procedures of calculating ANOVA for unequal replications of the experimental plot yield

Treatment (EP I, yield)	r_i	ΣY_{ij}	Y_i (mean)	ΣY^2_{ij}	Y^2_i/r_i
Traditional farming	8	2.73	0.34	1.91	0.93
Graded bund	7	2.09	0.30	1.31	0.62
Graded fanya juu	7	2.45	0.35	1.90	0.86
Grass strip	3	0.27	0.09	0.03	0.02
Total	25	7.54	1.08	5.15	2.43

Treatment (EP II, yield)	r_i	ΣY_{ij}	Y_i (mean)	ΣY^2_{ij}	Y^2_i/r_i
Traditional farming	7	2.49	0.36	1.13	0.89
Graded bund	7	2.31	0.33	1.01	0.76
Graded fanya juu	7	2.80	0.40	1.60	1.14
Grass strip	4	1.32	0.33	0.50	0.44
Total	25	8.95	1.42	4.32	3.23

Explanations, see appendix 3

Appendix 6 ANOVA table for yield

EP I

Source of Variation	DF	Sum Square	Mean Sum Square	F**	1%
Among SCM (treatment)	3	0.16	0.16	1.23	4.87
Within SCM (error)	21	2.73	0.13		
Total	24	[illegible]			

EP II

Source of Variation	DF	Sum Square	Mean Sum Square	F**	1%
Among SCM (treatment)	3	0.03	0.01	0.29	4.87
Within SCM (error)	21	1.09	0.04		
Total	24	1.12			

Appendix 7 Sample calculation for ANOVA, runoff on EP I from appendix 3

Correction factor (CF)

$$CF = \frac{Y_i}{\sum r} = \frac{(10534)^2}{27} = 4110226.4$$

Total sum of squares (TSS) =

$$TSS = \sum Y^2 - CF = 442968.29 - 4110226.4 = 312741.9$$

Treatment sum of squares (tSS)

$$tSS = \frac{(Y_1^2 + Y_2^2 + ... + Y_i^2)}{r} - CF = 4267718.72 - 4110226.4 = 157492.3$$

Error sum of squares (ESS)

$$ESS = TSS - tS = 312741.9 - 157492.3 = 155249.6$$

The mean sum of squares can be computed from treatment SS and error SS and degree of freedom:
Mean sum of squares for treatments = 157492.36/3 = 52497.45
Mean sum of squares for error = 155249.57/23 = 6749.98
F value (Fisher test) is the ratio of treatment mean sum of squares and error mean sum of squares; F = 52497.45/6749.96 = 7.8
The critical value at 1% level of significant for 3 and 23 degree of freedom (4.76) is a tabulated value.
Explanation of symbols see section 3.5.

Appendix 8 Comparison of means for runoff and soil loss

EP I, Runoff (Probability, 1%)	Grass strip	G/Fanya Juu	G/Bund	Traditional farming
Means	273.31	350.50	361.74	501.34

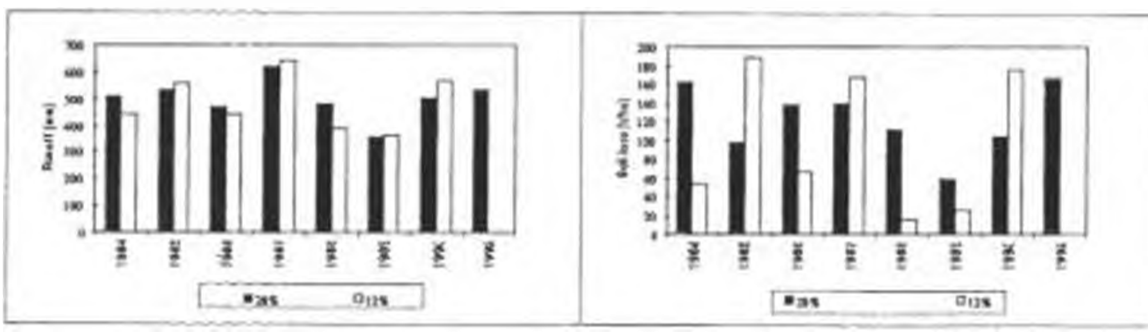
EP I, Soil loss (Probability, 1%)	Grass strip	G/Fanya Juu	G/Bund	Traditional farming
Means	30.30	56.54	58.24	122.1

EP II, Runoff (Probability, 1%)	G/Fanya Juu	G/Bund	Grass strip	Traditional farming
Means	263.63	303.75	401.37	451.50

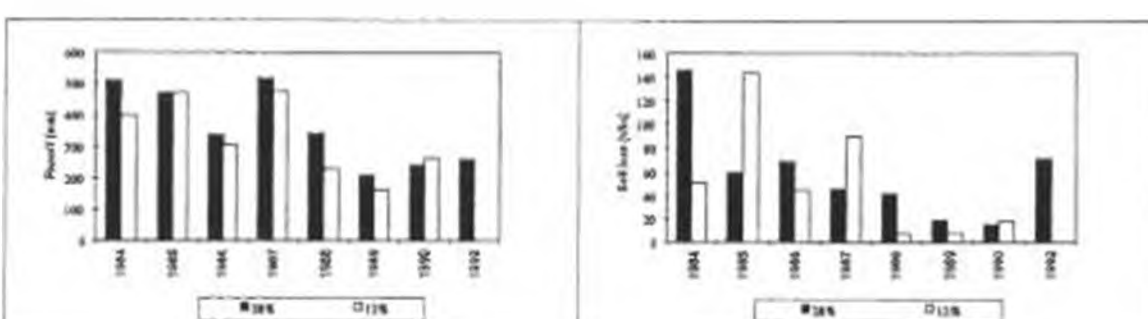
EP II, Soil loss (Probability, 1%)	G/Fanya Juu	Grass strip	G/Bund	Traditional farming
Means	23.64	36.10	47.65	88.16

Appendix 9 Effect of slope on runoff and soil loss under similar soil conservation techniques

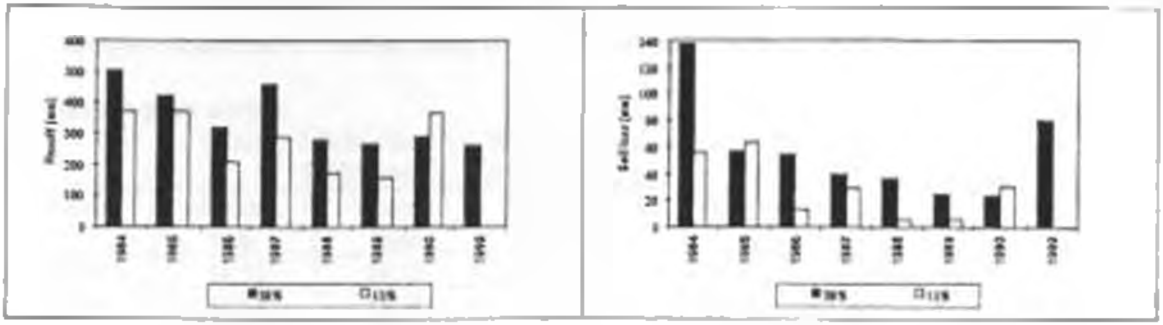
Appendix 9.1 Control Plots



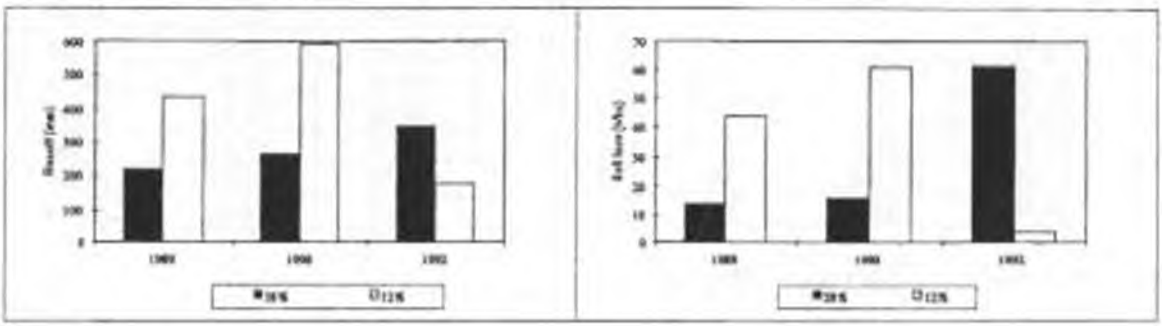
Appendix 9.2 Graded bund



Appendix 9.3 Graded fanya juu



Appendix 9.4 Grass strips



Appendix 10 Methods used by SCRP to calculate Erosivity

1. Sample calculation of erosivity using the Wischmeir and Smith (1978) method.

Observation period:

From 2/5/86 (date) 09:30 (time)

To 5/5/86 (date) 09:00 (time)

Date	Starting time	Ending time	Duration (min)	N	I	Y	E*
4/6/86	14:51	14:52	01	0.01	0.60	190.26	1.90
4/6/86	14:57	15:12	15	1.03	4.12	264.73	272.67
4/6/86	15:12	15:17	05	0.22	2.64	247.52	54.46
4/6/86	15:17	15:20	03	0.02	0.40	174.58	3.49
4/6/86	15:57	16:01	04	0.07	1.05	211.89	14.83
4/6/86	16:01	16:09	08	0.02	0.15	136.67	2.73
4/6/86	16:09	16:12	03	0.03	0.60	190.26	5.71
4/6/86	16:12	16:15	03	0.03	0.60	190.26	5.71
4/6/86	16:27	16:30	03	0.03	0.60	190.26	5.71
4/6/86	17:39	17:43	04	0.17	2.55	246.18	41.85
4/6/86	17:43	17:52	09	0.04	0.27	158.91	6.36
4/6/86	20:48	22:00	72	0.17	0.14	134.46	22.86
				a = 1.86	E = 438.3	I_{30} = 2.54	b = 11.10

Explanations

N = Amount of rainfall in the interval in cm

I = Intensity of rain in the interval in cm/hr

Y = Energy of one cm of rain in the interval

= 210 + 89logI in Joules/m^2

E* = Energy of rain in the interval

= NY in Joules/m^2

I_{30} = Maximum 30 minute intensity during the rainfall period in cm/hr

E = Energy of storm (for the whole period)

= ΣE* in Joules/m

a = Total amount of rainfall during the period

b = Erosivity (EI_{30}) in Joules/mh

Source: SCRP data base

2 Sample calculation of erosivity using the KE > 25 method.(Hudson, 1981)

Rainfall	**Period**					
	Date		Intensity	Amount	Energy	Total
No	From	To	Classes	(mm)	J/m^2mm	(col.4 x col.5)
1	1/5/86	4/5/86	0 - 25	39.25	-	-
			25 - 50	4.7	27.5	129.3
			50 - 75	1.0	27.9	27.9
			> 75	0.0	0.0	0.0
						157.2 J/m^2
2	4/5/86	13/5/86	0 - 25	14.3	-	-
			25 - 50	15.2	26.2	398.2
			50 - 75	0.0	0.0	0.0
			> 75	0.0	0.0	0.0
						398.2 J/m^2
3	13/5/86	2/6/86	0 - 25	36.9	0.0	0.0
			25 - 50	0.0	0.0	0.0
			50 - 75	0.0	0.0	0.0
			> 75	0.0	0.0	0.0
						0.0 J/m^2

Source: SCRP data base

Appendix 11 Questionnaire

A. Farmers Questionnaire

No.: ______________________________
Date: ______________________________
Wereda ______________________________
Sub catchment: ______________________________
Distance from the RS ______________________________
Name of Resp.: ______________________________

1 General information

1. Name of respondent ______________________________
2. For how long have you cultivated your current field ______________________________
3. Your holding size (ha) ______________________________
4. Number of animal holding Cattle Sheep/Goat
5. Major crops grown ______________________________
6. Major cash crop ______________________________
7. Other source of income ______________________________

2 On farm activities

1. Is your farm treated with conservation measures? yes--------no--------

2. What kind of soil and water conservation measures do you have in your farms, if not why? ________

3. What are the purposes of soil and water conservation measures? ______________________________

4. How and when did you learn about soil and water conservation measures? ______________________________

5. Which of the measures that were used have been effective in conserving the soil? ______________

6. On what gradient of slope do you construct terraces? (in order of priority) ______________________________

7. Which of the measures have had beneficial impacts on the livelihood of your household? (in order of priority) _
____

8. What is the width between bunds? ______________________________

9. Why do you choose this width? ______________________________

10. Do you have a problem during farming due to soil and water conservation measures? ____________

11. How often do you maintain the soil and water conservation measures? ______________________________

12. Organization of labor (family or other) ______________________________

13. Do you have any change in yield due to soil and water conservation measures?

High ______________ Low ______________ not known ______________

14. What other benefit do you get from soil and water conservation measures? ______________________________

15. Have you faced any constraints in practicing soil conservation measures on your farm? ______________

16. If so, what are the constraints you have faced? ______________________________

17. What are the possible solutions for the problem? ______________________________

B. DA/Technicians' Questionnaire

No.: ____________________
Date: ____________________
Wereda: ____________________
Sub catchment: ____________________
Distance from the RS ____________________
Name of Resp.: ____________________

1 General Information

1.1 Work experience in general ____________
1.2 Work experience in conservation works ____________
1.3 Period of service in the area/sub catchment ____________
1.4 Experience in different climatological zones ____________
1.5 Educational standard ____________
1.6 Special training ____________

2 Planning on catchment/sub catchment level

2.1 Planning/implementation of soil conservation activities were sufficiently flexible in relation to specific site conditions

2.2 How is a decision made for treating the catchment or sub catchment____________
2.3 Has there been land use planning made for the catchment/sub catchment?
Yes__________ No __________
2.4 If the answer is yes, who participated in the planning and how wasit done?

3 On farm activities
3.1 Initial design
3.1.1 Does the SC activities have been done on farmers' fields?
Yes__________ No __________
3.1.2 How was the work initially designed?____________
3.1.3 Where the farmers clear about the specifications of the work?
Yes__________ No __________
If yes, how?____________
3.1.4Were the farmers well informed about the eventual use of the results of soil conservation activities?
Yes__________ No __________
3.2 Appropriateness
3.2.1 How was decision made on the type of structures have been built on the farmers' fields?__________
____
3.2.2 What was the control mechanism that the structures were done correctly?
3.2.3 The necessary waterways provided for the graded bunds Yes__________No __________
Comments:____________
3.2.4 There is cutoof drain arrangement for level bunds
Yes__________ No__________
Comments:____________
3.2.5 The spacing of the bunds in relation to the slope of the area is
a) too wide____________
b) unnecessarily narrow____________
c) optimum____________
3.2.6 Do you see that the farmers build structures different from what they were told to do? Yes__ No
If yes, state the reasons

3.2.7 Are farmers capable to maintain the structures on their own?Yes________ No ___________

3.2.8 Do the farmers show the interest to maintain the structures without food payment?Yes_____ No

3.2.9 Do farmers use conservation based farming? Yes ______________ No ___________

3.2.10. How many farmers (%) in your area have soil and water conservation measures?

3.2.11. Give the reason why some farmers do not have soil and water conservation measures? ___

3. 2.12 Do you know why they choose that kind of soil and water conservation measures?______

3.2.13. What width of the terrace do the farmer used?____________________

3.2.14. Do you know why they choose these widths?______________________

3.2.15. What kind of soil and water conservation measures are commonly used in your area? (in order of priority)___________________________________

3.2.16. Please write advantages and disadvantages according to your opinion of level bund, graded bund, level fanya juu, graded fanya juu and grass strips ______________

3.2.17 State the percent coverage for different soil conservation measures (total = 100%)

- Level stone bund
- Graded stone bund
- Level soil bund
- Graded soil bund
- Grass strips
- Traditional ditches
- Agroforestry (including scatter trees)
- Trash line
- Others

3.2.18 Do farmers use any kind of indigenous soil and water conservation measures? If yes, list them in the order of importance

3.3 Change in output

In your opinion, do you believe there is change in output as a result of soil conservation activities? Explain: high:_______________low:_______________not known_______________

3.4 Are your satisfied that the job was done in a good way? Yes______ No ____

If yes or no comment compare with the observation _____________

3.5 Do you believe that the community has the capacity maintain the SC structures?Yes No ____

3.6 Do you believe that food payment is still necessary for the construction and maintenance of SC structures?________________________________

3.7 What impact do you see on FFW activities? ____