IMPACT OF TERRACE DEVELOPMENT AND MANAGEMENT ON SOIL PROPERTIES IN ANJENI AREA, WEST GOJAM

BY:
ALEMAYEHU ASSEFA

JULY, 2007
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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER’S IN GEOGRAPHY AND ENVIRONMENTAL STUDIES

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**Acknowledgements**

First of all, I would like to thank the Almighty God since everything is done through the help of him.

My deepest gratitude goes to my advisor Dr. Aklilu Amsalu for his constructive comments which was helpful for strengthening the study.

My heart-felt gratitude extends to my mother W/ro Almaz Wasihun for providing me with moral and financial support during my educational career.

I am also happy to forward my acknowledgement to Ministry of Agriculture and Rural Development, Amhara Regional and Agricultural Institute (ARARI), and JACS HoA (NCCR N-S).

Farmers of the Anjeni area who were willing to provide their opinions as well as the data collectors are also appreciated.

Finally, my thanks extend to all my families especially Ato Assefa Ayele and Ato Yilkal Goshu, and to my friends who helped me in one way or another.
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Abstract

Ethiopia has been facing land degradation problems. These problems are among the factors that have contributed to the outbreak of famines in the country that initiated the Government of Ethiopia and its foreign partners to emphasize on SWC at the severely eroded areas (mainly at the catchments level). Such practice mainly incorporated physical SWC measures including terraces. However, these measures have failed to bring the desired outcomes. That is, they failed to improve the productivity (fertility) of the already degraded areas.

The objectives of this study were to identify the difference between physical and chemical properties of terraced and non–terraced farm plots and explore the opinions of farmers on construction, maintenance, problems and benefits of terraces in Minchet catchment and its surrounding areas in Anjeni, West Gojam. Soils were sampled from three slope positions (upslope, middle slope, and downslope) as well as from three locations on the plot (upper, middle, and lower) under cultivation of terraced and non–terraced plots. The questionnaire survey using random and purposive sampling techniques was also conducted to generate data on the perceptions of household heads of terrace users.

The laboratory analysis indicated that the mean total nitrogen, organic matter, and available phosphorus contents of the non–terraced farm plots are relatively better than the terraced ones. The available potassium and CEC of both plots are found to be high. The PH value is found acidic while the texture of the sampled soils is more of clay. Thus, the soil parameters of the terraced plots need to be amended by applying appropriate supportive conservation measures that could enhance soil fertility.

The questionnaire survey of household heads revealed that the farmers strongly appreciated the ability of terraces in reducing soil erosion and increasing productivity. They showed their interests in continuing by adopting this SWC measure. However, farmers also noted the concentration of water at the lower section which causes a plant disease called "Wag" for barley, inconvenient to dig drainage ditches, the elevated terrace risers prevent the oxen not to plough the two corners (the upper and lower most ends) of the terrace bench, the upper section losses its moisture easily than the lower one, hiding place for rodents, and the terrace is too narrow making farming difficult as the major problems of terraces.

As indicated above, the laboratory analysis and the questionnaire survey contradict each other. However, although the soil samples are small, they are collected following a standard procedure. Thus, the reliability of mainly the farmers’ opinions is doubtful which needs further research.
### Abbreviations

<table>
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<tr>
<td>ARDU</td>
<td>Arsi Rural Development Unit</td>
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<tr>
<td>CEC</td>
<td>Cation Exchange Capacity</td>
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<td>CSA</td>
<td>Central Statistical Authority</td>
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<tr>
<td>DA</td>
<td>Development Agent</td>
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<td>EHRS</td>
<td>Ethiopian Highlands Reclamation Study</td>
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<td>FAO</td>
<td>Food and Agricultural Organization</td>
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<td>FFW</td>
<td>Food-For-Work</td>
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<td>GOs</td>
<td>Governmental Organizations</td>
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<tr>
<td>IIRR</td>
<td>International Institute of Rural Reconstruction</td>
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<tr>
<td>ILRI</td>
<td>International Livestock Research Institute</td>
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<tr>
<td>m asl</td>
<td>meter above sea level</td>
</tr>
<tr>
<td>NGOs</td>
<td>Non-Governmental Organizations</td>
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<td>NPK</td>
<td>Nitrogen, Phosphorus, Potassium</td>
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<tr>
<td>NRC</td>
<td>National Research Council</td>
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<td>PA</td>
<td>Peasant Association</td>
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<td>PH</td>
<td>Power of Hydrogen</td>
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<td>SCRP</td>
<td>Soil Conservation Research Programme</td>
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<td>SIDA</td>
<td>Swedish International Development Co-operation Agency</td>
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<td>SWC</td>
<td>Soil and Water Conservation</td>
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<td>WFP</td>
<td>World Food Programme</td>
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CHAPTER ONE

1. INTRODUCTION

1.1 Statement of the problem

Ethiopia is a relatively large country with a variety of soil types and climatic conditions. It has abundant water resources, diversified flora and fauna, and substantial underground resources. Yet, the standards of living of the people remain at a dismal level. Moreover, studies show there is substantial mismanagement of our natural resources in the form of over utilization of soils (Dessalegn and Taye, 2006).

Each year in Ethiopia it is estimated that 1.5 billion tonnes of top soil are washed away from their original location, which is an average of about 30 tonnes per hectare in the highlands, and about 40 tonnes a hectare from cultivated land (Hurni, 1987). Indeed, annual losses of up to 300 tonnes a hectare have been recorded in the case of sloping fields ploughed to a fine tilth for the tiny-seeded traditional cereal, teff. The typical Ethiopian farm household of about six persons now harvests less than a tonne of grain a year – less than enough for the barest subsistence diet – and crop yields are steadily declining due to erosion and exhausted fertility (Harrison, 1987). Hence, such conditions call for strong conservation works.

Soil conservation work in Ethiopia has been closely associated with food-for-work (FFW) since the Wello drought of 1972-74 when WFP provided food as an incentive for participation in communal labour. Under the WFP project, conservation works (stone terraces, earth bunds, tree planting, etc) have been carried out in 35 severely eroded catchments, seven of which are in Wello (7187 km²) (SIDA, 1987).
Since the early 1980s, the Ethiopian Government, with aid from international agencies, has been active in conservation work. A package of conservation measures has been developed usually employing terraces, bunds, tree planting and closure of grazing areas. Between 1976 and 1988 food-for-work (FFW) programmes funded the construction of 800,000 km of soil and stone bunds on cultivated land; 600,000 km of hillside terraces were built; and 80,000 hectares were closed for regeneration and for afforestation of steep slopes (Constable and Belshaw, 1989; Wood, 1990 cited in Eyasu, 2002).

Maintenance of soil fertility is crucial to the achievement of sustainable agriculture as the soil contains the nutrients, stores the water and provides the rooting medium essential for plant growth. Consequently, the manner in which soils are managed has a major impact on productivity and sustainability (Scholes et al 1994 cited in Eyasu, 2002). For example, in support of the main hypothesis of this study Amemiya et al (2002) explained that terracing is more effective for erosion control on slopes than strip cropping and contouring because it divides the slope into discrete segments and reduces the gradients of the cultivated parts. Although there may be soil movement within terrace intervals, most of this material accumulates in the terrace channel or in ponding areas. With some types of terraces, more than 95 percent of the detached soil particles remain on the land.

Anjeni, the study area, is the place where we find SWC station founded by Soil Conservation Research Programme (SCRP). In 1985 first conservation measures were constructed outside the catchment and from February to April 1986 the catchment was conserved with graded fanya juu bunds on cultivated land and other measures outside, for which first experiences had been gained in another SCRP research site, Andit Tid area in Northeast Shewa. In Anjeni the conservation was not carried out
through a food-for-work campaign, but instead the local communities who were participating in conservation works were offered a clinic as a social incentive (Ludi, 2004).

Since the study area is located in a favourable altitude (around 2500 m asl) and has got good climatic conditions, it is densely populated. As a result, it is intensively cultivated with no fallow periods which lead to high runoff, soil erosion and sediment loss. Thus, the objective of this study was to examine the impact of terraces in improving physical and chemical properties of the soil as compared to non-terraced farm plots in the wider Anjeni area. It was also intended to explore the opinions of farmers’ on the construction, maintenance, benefits and problems of terraces. Finally, recommendations on how to address possible problems associated with these types of soil conservation measures are forwarded.

1.2. Objectives of the Study
The general objective of this research is to examine the impacts of terrace development on soil properties in Anjeni area. The specific objectives include:

- To understand the construction, maintenance and development of terraces;
- To investigate the effects of terraces on soil physical and chemical properties and compare with the non-terraced farm plots; and
- To explore the farmers’ opinion on the benefits and impacts of terraces in mitigating the problem of soil degradation.

1.3. Research Questions
Based on the objectives listed above, the following research questions are prepared:
• How are the terraces constructed and maintained in the area?
• Is there a difference between terraced farm plots and non-terraced farm plots in terms of the physical and chemical soil properties?
• What are the opinions of the farmers’ on the problems and benefits of terrace development?

1.4 Data Sources and Methods

1.4.1 Data Sources
The study used both primary and secondary data. The secondary data were obtained from various published and unpublished sources of the governmental and the non-governmental organizations. Books, journals, internet sources, research reports, archives and records were employed for acquiring the necessary information.

The primary data were obtained through field survey, laboratory analysis, and questionnaire survey.

1.4.2 Sampling Methods
In order to generate data for the second objective, field survey was conducted. A reconnaissance survey was carried out for identifying representative soil sampling plots. Sampling sites were selected from both the terraced farm plots found in the Minchet (Anjeni SWC Research) catchment and the non-terraced farm plots located outside the catchment. In the case of the terraced plots, the sampling plots refer to the area between the two successive terraces. In the case of the non-terraced plots, the sampling plots refer to the area under cultivation which is found between successive farm boundaries.
Thus, for the terraced plots, auger hole observations were taken from each of the three slope positions (i.e. upslope, middle slope, and downslope) as well as from three sites within the inter-terrace area, that is one from the bottom of the bund, one from the middle, and one from the top of the next bund through purposive sampling technique. For the non-terraced plots, auger holes were opened on three slope locations and on three positions on the considered piece of land under cultivation, that is one on the upper end of the plot, one on the middle, and the other on the lower end of the plot through again purposive sampling method. Following these procedures it was totally taken 45 soil samples (27 from terraced farm plots and 18 from non-terraced farm plots). These samples are taken from 15 farm plots (9 of them are terraced farm plots while the remaining are non-terraced farm plots). The reason for selecting these three slope positions is that soils and their drainage conditions vary considerably over such areas. Furthermore, the SCRP did long-term series of productivity measurements using the same procedure, which can be used for comparing soil quality with agricultural production in these positions.

In order to meet Objective No. 1 and 3, a questionnaire survey was conducted with the intention of assessing farmers’ opinions on the construction, maintenance, problems and benefits of terraces. The samples for the questionnaire survey were selected considering the number of households residing in the study area (Anjeni PA). The PA under study consists of 333 households (CSA, 1994). Thus, the researcher selected 40 households, which is 12% of the total number of household heads through random sampling method. In addition, 10 household heads (3 % of the total) that have terraced plot(s) within the Minchet catchment as well as non-terraced plot(s) outside the catchment were selected through purposive sampling method. Formal and informal
discussions were held with farmers so as to generate additional information for the study.

1.4.3 Methods of Data Analysis

In order to address the specified objectives and to answer the given research questions, the study analyzed the data both qualitatively and quantitatively. The qualitative method was employed to analyze the opinions of farmers’.

The quantitative data was analyzed using tables, graphs and percentage. Such data, which was generated from soil laboratory analysis (the soil samples are analyzed at Holeta Agricultural Research Center) was properly tabulated and described using standard soil description guidelines. The quantitative information from the questionnaire was also tabulated and analyzed using appropriate quantitative method.

1.5 Significance of the Study

It is possible to say that the farm plots treated with terraces face similar run- off but less sediment loss than the ones which are not treated. Hence, due emphasis should be given in selecting appropriate soil conservation technique for a particular area. However, most developing countries undertake too little research on runoff management. The works done in many countries are often inadequate to provide proven alternative practices for erosion control and soil moisture conservation. Although some basic concepts in this field are potentially of universal application, conservation practices developed in one country need testing and verification, especially in relation to rainfall, soil and local cropping practices, before they are adopted elsewhere (FAO, 1993).

With regard to the Anjeni area, a number of studies were conducted focusing on different issues. For example, Kefeni Kejela (1987) focused on
This study differs from the previous studies for the fact that: 1) it shows the difference between soil physical and chemical properties of terraced and non-terraced farm plots, and 2) it explores current perceptions of farmers’ on the construction, maintenance, problems and benefits of terraces since they have used terraces for conserving soils for more than 20 years.

Generally, this study is intended to supplement the previous studies and to give recent information for the people in the area, the GOs, the NGOs, and the agricultural experts who are engaged in SWC.

1.6 Scope of the Study
Since it is not possible to cover the whole aspects of the study area with the available time and resources, it is advisable to limit the study size and the scope of the problem to a manageable size. Hence, the study focused on the representative sites in Anjeni area. It also tried to see the soil physical and chemical properties difference between the terraced farm plots within the catchment and the non-terraced farm plots outside the catchment. It also investigated the farmers’ perceptions on the construction, maintenance, problems and benefits of terraces only, not any other physical conservation methods.

1.7 Limitation of the Study
Ignoring the effect of other factors, this paper assumes that terraces play a major role in enhancing soil properties (soil fertility). However, the truth is that soil fertility can be maintained because of the combined factors, not because of terraces alone.
Because of the constraints of time and budget, the researcher doesn’t think that enough number of soil samples is taken for making comparisons between soil parameters of terraced and non-terraced farm plots.

1.8. Organization of the Paper

The paper is organized into five chapters. Chapter one is the introductory section. The review of related literatures is presented in chapter two. Chapter three deals with background of the study area. Research results and discussions are given in chapter four. The last chapter (i.e. chapter five) is concerned with conclusions and recommendations.
CHAPTER TWO

2. REVIEW OF LITERATURE

2.1 Land Degradation and Soil Conservation in Ethiopia

2.1.1 Land Degradation

Ethiopia is considered to be one of the least developed countries where agriculture had always played a central role in the country’s economy. Although agriculture has always been the mainstay of the economy, it is characterized by a very low or stagnant growth rate and a declining trend. This is mainly the result of the low productivity of the sector. The rapidly increasing population has led to a declining availability of cultivable land and a very high rate of soil erosion (Abera, 2003). Constable (1984) explained that the Ethiopian highlands are an ancient and conspicuously united part of the Earth’s surface, which by virtue of their location, have constantly been assailed by normal erosive forces in part generated by climatic phenomena originating from the surrounding desert, sea or forested lowlands.

The Ethiopian highlands have been settled for millennia, and agriculture has a matching history. Currently, the highland farming population grows with a rate of more than 3% per annum, and correspondingly the livestock population is increasing. These place more demand on more marginal land for cultivation and grazing uses, which lead to more devegetation, grazing lands degradation and soil degradation (Woldeamlak, 2003).

Land degradation is defined as a temporary or permanent decline in the productive capacity of land, or its potential for environmental management (Bezuayehu et al, 2002). On the other hand, Constable (1984) defined the degradation of soil as a long-term loss in its
productivity. It is not necessarily continuous and it may take place over a relatively short period between two states of ecological equilibrium.

Land degradation is the result of complex interaction between physical, chemical, biological, socio-economics and political issues of local, national or global nature. While the scale of global processes may be vast, they may be in a state of dynamic equilibrium, easily upset by human activities. Some of the causes of degradation are natural hazards, population growth, expansion of agriculture onto forests and marginal land, poverty, land ownership problems, political instability and maladministration, inappropriate agriculture, and large-scale expansion of irrigated agriculture (Taffa, 2002).

Land degradation is resulted due to soil erosion and nutrient depletion. Thomas and Yeshinegus (1984) indicated factors which have contributed to the erosion problem on cropland in the highland of Ethiopia as follows:

- The cultivation of teff for which a very fine seedbed is needed.
- The use of dung for fuel or sale and almost total failure to return it to the land.
- Delayed planting of certain crops after the onset of rains.
- The removal of almost all crop residues for fodder, fuel or sale.
- Cultivation up and down the slope.
- Shortening or elimination of the fallow period.

Soil erosion reduces soil productivity principally by adversely affecting soil nutrients, infiltration of water and air into the soil, soil water holding capacity, soil tilth and the surface configuration of the soil. The extent to which soil losses affect its productivity depends on many factors
important among which are the land use type and management and the capacity of remaining soil to support plant growth (compared to the soil's capacity before the losses). Notwithstanding variations in such factors, soil erosion generally removes the more fertile portions of the soil so that the productivity capacity of the remaining soil is usually lower than it was before erosion (Constable, 1984).

The cause and effect relationship of land degradation is so complex, that is it can be viewed from different angles. The diagrammatic representation of such relationship is given below.

Fig1: Schematic Presentation of Cause and Effect of Land Degradation
As it is indicated in the previous sections, erosion causes loss of productivity. By implication, methods that arrest erosion or reduce it to an acceptable minimum should sustain productivity. This is because conserved fields are expected to show an increase in production relative to situation where erosion is allowed to continue, provided that other factors remain the same. Responses of farm plots to various conservation treatments, however, will vary over time and space depending on other influencing factors (Solomon, 1994).

It can be concluded that in Ethiopia as soil degradation is already so widespread, there is an urgent need to conserve the productive soil still remaining and to prevent the spread of soil degradation to areas not yet affected (Constable, 1984).

### 2.1.2 Soil Conservation in Ethiopia

Ethiopia is a country where soil degradation is prevalent at a tragic rate. The average annual rate of soil loss in the country is estimated to be 12 tons/hectare/year, and it can be even higher on steep slopes and on places where the vegetation cover is low. The amount of yield reduction as a result of the loss of topsoil each year is increasing substantially. This makes the issue of soil conservation not only necessary but also a vital concern if the country wants to achieve sustainable development of its agricultural sector and its economy at large (Abera, 2003). The EHRS estimated that if soil erosion continues unchecked, by the year 2010 some 38,000 sq. km of the highlands of Ethiopia will be down to bare rock and a further 60,000 sq. km will have a soil depth of 10 cm or below.

No country in Africa other than Ethiopia needed an effective conservation programme more urgently. Seven out of ten Ethiopians live in the mountainous highlands, where three fifths of all land has slopes over 16
percent (Harrison, 1987). Hence, the combined effects of physical and human induced factors compelled the Government of Ethiopia and its foreign partners to emphasize more on SWC than ever before.

In Ethiopia before the 1974 Revolution, the land management system was to impose long fallow periods when soil fertility was depleted. It might be controversial to assume that the land management system under feudal and tenant relations was good. On the other hand, during the era of the Derg regime (1974-1991), SWC and afforestation were applied more widely even if they failed in combating land degradation (Yohannes, 1999).

Prior to 1974, very little effort was made to combat degradation of the Ethiopian highlands. The drought of early 1970s, coupled with the new political approach to the country’s problems, gave birth to increase interest in SWC (Aggrey- Mensah, 1984). Before 1973/74, only a few adhoc soil conservation activities were practiced as part of other projects, e.g., the Arsi Rural Development Unit (ARDU) project. Following the drought, increased attention was given to soil erosion. The food resources that were made available to Ethiopia, mainly through the world food programmed (WFP) food- for- work (FFW) programme, played a significant role in the development of soil conservation programme (Kebede Tato, 1990 cited in SIDA, 1993).

The beginnings of the food –for- work by WFP can be traced back to the early 1970s drought. At first as pilot and demonstration ventures and then in 1980, as the full scale Rehabilitation of Forest, Grazing and Agricultural Lands Project. The rationale for the project was that there were people who needed the food and a degrading environment that needed the labour and effort of the people (Berhe, 1996).
Harrison (1987) pointed out that Ethiopia is the site of the World Food Programme’s biggest conservation effort in Africa. Like most WFP projects it provides food for hungry people not in the form of free handouts, but in exchange for hard work aimed at laying the foundations of food self-sufficiency. The project began in a small way in the northern provinces of Eritrea, Tigray and Wello, after the 1972/73 drought. In 1980 it was expanded and now covers 44 densely populated catchment areas seriously affected by drought, land degradation and food deficit. The initial programme was ambitious enough, involving 44 million person-days’ work, to be carried out over a period of four years. The target was reached in only two years. In 1982 the programme was expanded again, and has now been extended up to 1989.

The issue of resource conservation has been given due attention by the Ethiopian government, its development partners and NGOs. Indeed, various interventions have been crafted at both national and local levels to address what is believed by many to be Ethiopia’s critical development challenge. Yet, it appears that such intervention should consider the added dimensions of secure resource entitlement and collective action to harmonize the environment-society relationship (Ayalneh, 2004). The conservation efforts that were started since 1970s and 1980s tried to introduce SWC measures in areas where soil erosion is severe and food deficit is widespread.

As it is indicated by many studies, emphasis was given for physical conservation measures. Eyasu (2002) argued that in the case of construction of soil conservation measures in Ethiopia emphasis should be shifted from the construction of bunds alone to the use of vegetative and agronomic measures that are most effective in erosion control. Indeed, land degradation can be mitigated by various combinations of structural vegetative or biological and agronomic measures chosen
according to the site conditions. Increased vegetative cover of the soil with in cropping through mulching, cover crops and intercropping is effective at reducing the impact of rainfall and increasing the soil’s resistance to erosion. Physical structures may still be necessary as they have an important role in reducing soil loss by runoff control, particularly for annual crops and no steeper slopes.

Despite all these efforts, many writers quoted that the SWC campaign was neither effective nor sustainable. For example, Aklilu (2006) showed that SWC activities in the highlands of Ethiopia are faced with several challenges. Despite extensive conservation interventions during the past decades, sustained adoption of the recommended measures by the farmers has not been as expected. Woldeamlak (2003) also noted that over the past few decades, the agricultural sector has failed to keep pace with growing demand for food. This is partly attributable to erosion-induced degradation of croplands. On the other hand, efforts of SWC made over more than two decades ended up with disappointing results. The problem has therefore persisted and will persist as a serious threat to the food security and development envisioned in the country’s policy documents.

### 2.2 Overview of Terraces in Ethiopia

Ethiopian farmers have long been aware of the problems associated with soil degradation, and have traditionally been conservation minded at the level of the farm. However, the knowledge, skills, survival strategies and risks faced by the farmers operating with low levels of external input have been ignored frequently by outsiders and experts promoting ‘modern’ conservation techniques (Kruger et al, 1996).
Certain soil management and soil conservation practices are well known in certain parts of Ethiopia. These include the use of traditional terracing, traditional ditches, mulching, etc (Million, 1992).

Terracing is one of the oldest means of saving soil and water (Dorren and Rey, 2004). It is a practice that was first adopted by the Aztecs* and the Incas** in South America (Keirle, 2002).

In Ethiopia terracing was practiced under traditional agriculture in the highlands of Tigray, in Northern and Northeastern Shewa, in the Chercher highlands in Harerghe and in the Konso region south of Lake Chamo in the eastern part of Gamo Gofa region (Huffnagel, 1961 cited in Thomas and Yeshinegus, 1984).

In Ethiopia soil conservation, classically as exemplified by terracing is not generally part of the traditional practice. There are, however, some notable exceptions. In the Konso area of southern Gamo Gofa, terracing has been the key to survival. The low rainfall (about 900mm) and comparatively short growing season (100-120 days) have meant that the water conservation benefits of the terraces are probably more important than the soil conservation ones. However, the rainfall pattern is characterized by high intensity, short duration storms making terracing virtually essential to preserve soil (Westphal, 1975 cited in Cloutier and Dejene, 1984).

On the other hand, Yeraswork (1995) reported that terracing was among the indigenous techniques of soil conservation employed by farmers of his study area (some selected places in Northern Shewa, and North and

---

*An early strong empire in Mexico.
**An early strong empire in Peru.
South Wello) even before the advent of the conservation and afforestation programme which was conducted by the Government of Ethiopia and its development partners after the 1972/73 Famine. It was a novelty introduced through the programme. It was not until the advent of the soil conservation and afforestation programme that the systematic bunding of cropland with the objective of terrace development began in earnest. Harrison (1987) noted that food-for work creates tangible assets, forests and terraces that will sustain food and fuel production in the future for the people of Ethiopia.

In most highland parts of Ethiopia, particularly in northern Shewa, it has been observed that some of the terraces, which were constructed by the joint efforts of WFP and the Government of Ethiopia, have been destroyed by the local farmers, while certain SWC methods such as stone terraces, cut-off drains, etc continued to be used (Million, 1996). Thomas and Yeshinegus (1984) added that much of the traditional terracing appears to have broken down due, partly no doubt to intensifications of land use and insecurity of tenure.

Generally, there is a growing consensus that the poor record of SWC in Ethiopia can be attributed to the lack of appreciation of indigenous practices by soil conservation experts and policy-makers (Kruger et al.1996). This is because the farmers did not participate fully at all levels of planning and implementation. Farmers were interested only in getting grain and oil, whatever SWC measures were constructed on their land (Million, 1996).

2.3 Classification of Terraces
To classify the various types of terraces, different criteria have to be used. They should be classified based on 1) Destination of the intercepted water, 2) Construction process, 3) Size of the terrace base and 4) Terrace
shape (FAO, 2000). The descriptions of the different types of terraces according to these criteria are indicated in the table given below.
### Table 1: General Classification of Terraces Based on Different Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Types of Terraces</th>
<th>Description</th>
</tr>
</thead>
</table>
| Destination of the intercepted water         | Absorption (or retention or level) terraces            | - Designed to accumulate and retain run off in the terrace channel.  
- Recommended for low rainfall areas, for permeable soils, and for land of less than 8% slope.  
- Are broad-based terraces.                   |
| Construction process                          | Graded (or diversion) terraces                         | - Designed to intercept run off and divert the excess water that has not infiltrated into protected water ways.  
- Recommended for high rainfall regions, for slightly or moderately permeable soils, and for slopes of between 8 and 20%.  
- Are narrow- or medium-based terraces.       |
| Size of the terrace base and distance of soil movement | Channel (or Nichols) terraces                          | - Are broad-based and are constructed by moving soil from the upslope side only.  
- Recommended for slopes up to 20%, for high rainfall regions, and for soils of low or medium permeability. |
| Size of the terrace base and distance of soil movement | Ridge (or Mangum) terraces                             | - Are constructed by excavating the soil from both sides (downhill and uphill).  
- Recommended for slopes less than 10%, for low rainfall regions, and for permeable soils. |
| Terrace shape                                 | Narrow-based terraces                                  | - Where soil movement is limited to about 3 meters.  
- Include contour ridges.                     |
| Terrace shape                                 | Medium-based terraces                                  | - Where soil movement is 3 to 6 meters.                                                                                                             |
| Terrace shape                                 | Broad-based terraces                                   | - Where soil is moved more than 6 meters (but normally less than 12 meters).                                                                     |
| Terrace shape                                 | Common (or normal) terraces                            | - Consist of a ridge or bank and a channel, which may be constructed on a gradient or level.  
- Recommended for slopes less than 20%.  
- Can be narrow-, medium- or broad-based terraces. |
| Terrace shape                                 | Bench terraces                                         | - Are a series of level or virtually level strips running across the slope at vertical intervals, supported by steep banks or risers.  
- Can be formed by excavation or may develop over time from a grass strip or fanya juu.  
- Recommended for lands with slopes in excess of 20%.  
- Require regular care and maintenance as a small break will result in large scale damage. |

Dorren and Rey (2004) indicated that the three types that are used most to characterize all existing terraces are: bench terraces, contour terraces and parallel terraces, although this subdivision mixes different criteria. Contour terraces follow exactly the contour lines of the terrain. Parallel terraces eliminate the production losses associated with contour terraces because they are constructed parallel to each other and, where possible, to the direction of field operations. Today the types most common on agricultural land in the U.S. are parallel terraces. These terraces are very suitable for fields with soils deeper than 15 cm and fairly-uniform slopes that are not too steep (generally less than 8 percent). In connection with this, Wheaton and Monke (2001) said that some terraces are constructed with steep back slopes that are kept in grass. Most, however, are broad-based having gently sloped ridges that are cultivated as a part of the field.

2.4 Benefits of Terraces
The aim of sound soil management is to maintain the fertility and structure of the soil (Morgan, 1995). Better management of the chemical and physical characteristics of the soil is critical to sustainability (NRC, 1991).

Posthumus and De Graaff (2005) mentioned the benefits of terracing as follows:

- Improved water availability due to water conservation, leading to higher actual evapotranspiration resulting in increasing yields.
- Less soil nutrient losses due to reduced soil erosion, and thus higher nutrient availability resulting in increasing yields.
- Increased lifetime of land for cultivation, particularly in the case of shallows.
- Amelioration of otherwise limited cropping conditions on steep slopes like the correction of the slope, enabling of irrigation, and change of microclimate.
- In the case of stone terraces, the stone refract the sun’s heat into the soil and thereby protect crops against frost (Alfaro, 1988 cited in Posthumus and De Graaff (2005) and the walls redirect the wind so that the crop is protected from excessive wind.

Terraces are of value on practically all soils except those that are too stony, sandy or shallow to permit practical and economical construction and maintenance (Daniel, 2005).

A lot of information is available indicating that properly constructed terraces can drastically reduce runoff and soil erosion. For example, the study by Lal (1995) shows that both the runoff and soil erosion from terraced catchment is lower than those from the non-terraced catchment (see Table 2).

Table 2: Runoff and Soil Loss from Terraced and Non-terraced catchments at Ibadan, Nigeria, from a single Rainstorm received on 6 July, 1981.

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Run off (mm)</th>
<th>Soil erosion (Mg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terraced</td>
<td>18.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Non-terraced</td>
<td>18.8</td>
<td>2.3</td>
</tr>
</tbody>
</table>


It may be concluded that terraces could considerably reduce soil loss due to water erosion if they are well-planned, correctly constructed and properly maintained. There are many examples showing that terraces have to be maintained to prevent processes leading to land degradation.
such as excessive soil erosion, gully formation and land sliding (Dorren and Rey, 2004).

### 2.5 Problems of Terraces

It cannot be stressed too strongly that the basis of effective control of runoff and subsequent erosion is effective ground cover be it dead or alive (Cloutier et al., 1984). This implies that SWC measures including terraces are not free from limitations. Terraces are mostly ineffective in controlling the detachment of soils. They are rather intended to supplement agronomic measures.

Terraces create difficulties for farmers. Unless the soils are deep, terrace construction exposes the less fertile sub soils and may therefore result in lower crop yields. On irregular slopes, terraces will vary in width, making for inefficient use of farm machinery, and only where slopes are straight in plan can this problem be overcome by parallel terrace layouts. Also, there is a risk of terrace failure in severe storms. When this occurs, the sudden release of water ponded up on the hillside can do more damage than if no terraces had been constructed (Morgan, 1995).

Soil erosion control by terracing is found to be the most expensive soil conservation practice. Therefore, terrace abandonment and terrace deterioration is nowadays observed more often (Dorren and Rey, 2004).

Generally, since terracing requires labour and capital investment and causes some inconvenience in farming, it should be considered only where other cropping and soil management practices, singly or in combination, will not provide adequate erosion control or water management. In steep land slopes where simple vegetative control measures and agronomic practices are not effective in controlling erosion then terraces would be inevitable (Daniel, 2005).
CHAPTER THREE

3. BACKGROUND OF THE STUDY AREA

3.1 Location and Size

Anjeni is located at an approximate geographical coordinate of latitude 10°40’N and longitude 37°31’E. It is bordered by the Debre Markos- Bahir Dar road, 15 km north of Dembecha town on the rural road to Feres Bet and 65 km NNW of Debre Markos (Kefeni, 1995; SCRP, 2000; Ludi, 2004). In administrative terms, Anjeni lies within Dembecha Wereda of West Gojam Administrative Zone, Amhara National Regional State.

Anjeni PA covers an area of 575 ha and comprises of a SWC Research Unit with the exception of a small area that belongs to the Jenhala PA. The research site in Minchet catchment, which was established in March 1984 by SCRP, covers an area of 108.2 ha, but the size of the hydrological catchment is about 113.4 ha (SCRP, 2000).

Fig. 2: Location of the Study Area.
Fig. 3: Aerial Photo of a Terraced Minchet Catchment and its Surroundings.
Source: SCRP
3.2 Topography and Geology

Although the mean altitude of Anjeni area is about 2,285 m asl, it actually varies between 2,100 and 2,500 m. The research catchment lies within an altitudinal range between 2,407-2,507 m asl. This includes the greatest part of the plateau remnants, almost all of the plateau foot slopes, and all of the alluvial plain. Anjeni is located at the foot of an isolated mountain massif, the Choke Mountains while the topography in the research catchment is dominated by undulating slopes. Besides, the topography of Anjeni is typical of Tertiary volcanic landscapes, it has also been deeply incised by streams, resulting in the current diversity of land forms (Kefeni, 1995; SCRP, 2000; Ludi, 2004).

Geologically speaking, the Anjeni area including Anjeni SWC Research Unit belongs to the basaltic Trapp series of Tertiary volcanic eruptions and is similar to most parts of central Ethiopia (SCRP, 2000). Kefeni (1995) quoting the geological map of Ethiopia and Mohr (1971) described the geological situation of the research unit as it lies over Precambrian crystalline bedrock. This granite and gneiss bedrock is covered by deposits of Mesozoic sedimentary rocks which itself lies under tertiary basalts and tuffs of the Trapp series that include rare rhyolites which are responsible for the development of the easily visible flatter terraces and steeper slopes.

3.3 Climate

Agroclimatically, Anjeni area is grouped under Wet Weyna Dega. It is characterized by a unimodal rainfall. It receives rainfall only from May to September (SCRP, 2000). The temperature data from Anjeni SWC Research Unit indicates that the lowest daily air temperature is 0°C while the highest is 33°C.
Fig. 4: Mean Monthly Minimum and Maximum Air Temperatures of Anjeni Area (1984-1993).

According to the SCRP database (1984-1993), March is the warmest month with mean monthly minimum and maximum air temperature of 9.5°C and 26.1°C. The highest absolute mean monthly air temperature is in April and May. August as the coldest month has a mean monthly minimum and maximum air temperature of 10.4°C and 19.4°C.
Table 3: Mean Annual Minimum and Maximum Average Temperature (1984-1993)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Min.Avg</td>
<td>9.5</td>
<td>9</td>
<td>9.3</td>
<td>9.4</td>
<td>8.5</td>
<td>8.5</td>
<td>8.8</td>
<td>9.2</td>
<td>9.3</td>
<td>8.8</td>
</tr>
<tr>
<td>Max.Avg.</td>
<td>24.1</td>
<td>25</td>
<td>24.9</td>
<td>23.9</td>
<td>22.6</td>
<td>22.2</td>
<td>23.1</td>
<td>22.6</td>
<td>22</td>
<td>22.6</td>
</tr>
<tr>
<td>Absolute</td>
<td>16.8</td>
<td>17</td>
<td>17.1</td>
<td>16.6</td>
<td>15.6</td>
<td>15.3</td>
<td>15.9</td>
<td>15.9</td>
<td>15.7</td>
<td>15.7</td>
</tr>
</tbody>
</table>

**Note:** Air temperature for 1984 is incomplete.


The all year averages of mean annual minimum and maximum air temperatures are 9.03°C and 23.3°C. The highest absolute mean annual air temperature is recorded in 1986.

According to monthly rainfall distributions, Anjeni area is commonly known as having relatively longer growing period from June to September. The rainfall distribution during this period varies between 240.18 and 398.20 mm with a peak rainfall in July. This period is contributing about 77% of the annual rainfall and about 12% of the annual rainfall is in May and October. According to the SCRP database (1984-1993), the minimum and maximum annual rainfalls were 1159 mm in 1991 and 1855 mm in 1988.
Fig. 5: Mean Monthly Rainfall Distribution of Anjeni Area (1984-1993)

**Note:**
- Daily rainguage data for 1984 is incomplete.
- The given rainfall data is measured in Pluviometer.


### 3.4 Soils

The soils of Anjeni SWC Research Unit have developed from a volcanic diversity of landforms. The soils have developed from a volcanic basement and reworked materials of Tertiary volcanic eruptions, and rarely from sedimentation processes (SCRP, 2000).
Table 4: Major Soil Units and Sub-groups, Their Area Coverage in the Minchet Catchment, Anjeni

<table>
<thead>
<tr>
<th>Major Soil Units</th>
<th>Soil Sub-groups</th>
<th>Area (ha)</th>
<th>Soil depth range (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alisols</td>
<td>Humic Alisols</td>
<td>20.9</td>
<td>65-200</td>
</tr>
<tr>
<td></td>
<td>Haplic Alisols</td>
<td>20.6</td>
<td>50-110</td>
</tr>
<tr>
<td>Nitosols</td>
<td>Haplic Nitosols</td>
<td>17.2</td>
<td>50-150</td>
</tr>
<tr>
<td></td>
<td>Humic Nitosols</td>
<td>6.6</td>
<td>100-200</td>
</tr>
<tr>
<td>Cambisols</td>
<td>Dystric Cambisols</td>
<td>18.9</td>
<td>70-100</td>
</tr>
<tr>
<td>Regosols</td>
<td>Eutric Regosols</td>
<td>10</td>
<td>&lt;25-50</td>
</tr>
<tr>
<td>Lixisols</td>
<td>Haplic Lixisols</td>
<td>4.8</td>
<td>100-150</td>
</tr>
<tr>
<td>Luvisols</td>
<td>Vertic Luvisols</td>
<td>4.2</td>
<td>120-150</td>
</tr>
<tr>
<td>Acrisols</td>
<td>Haplic Acrisols</td>
<td>2.6</td>
<td>100-150</td>
</tr>
<tr>
<td>Leptosols</td>
<td>Lithic Leptosols</td>
<td>2.4</td>
<td>&lt;25-50</td>
</tr>
</tbody>
</table>

Source: Gete, 2000

Gete (2000) found out that the soils of Anjeni are rather complex and vary with in short distances. The lower valley bottoms and concave parts of the catchment are predominantly covered with deep, well-weathered Alisols (41%), while moderately deep red Nitosols (23.8%) cover the middle gently sloping (convex to linear) parts of the catchment. The steep upper slopes, mainly convex in shape, are covered with very shallow Regosols and Leptosols (12.4%) probably derived from Nitosols in the truncation process of soil erosion. The upper top parts of the catchment and some parts of the gently sloping area in the middle are covered with moderately deep, young Dystric Cambisols (19%). These soils are traditional soils with less developed B-horizons. Other soils like Luvisols, Lixisols and Acrisols are also found in small pockets in the catchment.
3.5 Natural Vegetation

Natural vegetation has almost disappeared in Anjeni area, although some bushes and woody trees can still be observed. These include Hagenia abyssinica (Koso in Amharic), Acacia S.P (Grar), Bamboo (Kerka), Rubus aretalus (Enjor), Schefflera abyssinica (Getem), Augaria salicifolia (Koba), Polystachya (Anfar), Erythrina tomentosola (Homa), Embelia Schimperia (Enkok), Bersama abyssinica (Azamer) and Rosa abyssinica (kega) (Kefeni, 1995).

3.6 Agriculture and Farming System

Farmers of Anjeni area are leading their life with subsistence farming. They make use of both traditional and introduced conservation measures to enhance the fertility of their farm plots.

The research unit is part of the Blue Nile river basin. The land around the unit is almost exclusively used for traditional agricultural purposes, primarily crop production and cattle raising (Kefeni, 1995).

In Anjeni, major crops grown are barley, teff, wheat and maize as grains, lupine (gibbto) and beans as pulses, plus linseed. In addition, minor parts of the cropped area are covered with oil seeds (nug). Average crop yield per hectare was between 0.6 and 0.9 t/ha (Ludi, 2004).

The mean size of land holdings of Anjeni PA in 1986 and 1991 were 2.2 ha and 1.9 ha per household respectively (SCRP, 2000). Ludi’s (2004) study conducted in 1998/99 covering 15 households of the research catchment shows that poor households on the average cultivate only 1.5 ha and rich households only 2.5 ha. On the average, land holdings decreased from 2.95 ha in 1986 to 2.1 ha per household in 1998/99.
Kefeni (1995) stated that in many cases land left for cattle raising and hay production is either severely eroded and unsuitable for cultivation, or poorly drained land on the valley floors.

3.7 Population

The total population of Anjeni PA is 1497 while its total number of households is 333 (CSA, 1994). According to SCRP’s standard survey, the population density in 1991 in the area of the PA under study was 193 inhabitants per sq. km.

Table 5: Number of Households and Persons in Anjeni SWC Research Unit

<table>
<thead>
<tr>
<th></th>
<th>1984</th>
<th>1991</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household recorded</td>
<td>85</td>
<td>95</td>
</tr>
<tr>
<td>Persons recorded</td>
<td>430</td>
<td>512</td>
</tr>
</tbody>
</table>

**Note:** The samples of 1984 and 1991 include all households with a share of land inside the research catchment.

Source: SCRP, 2000
CHAPTER FOUR

4. RESULTS and DISCUSSIONS

4.1. Analysis of Physical and Chemical Properties of Terraced and Non-Terraced Farm Plots

SWC measures like terraces reduce soil erosion if they are correctly constructed and maintained, and if they are compatible with local environmental conditions. Thus, these measures prevent the removal of the topsoil which constitutes important nutrients for plant growth.

As given in the previous sections, one of the objective of this study is to make comparisons between terraced farm plots in the Minchet catchment and non-terraced farm plots outside the catchment in terms of their physical and chemical properties of the soils. To do so, the result of the laboratory analysis of selected soil parameters is given below.

The rating of total nitrogen, organic carbon, available phosphorus, available potassium and CEC contents of terraced and non-terraced farm plots is given based on Landon (1991) while the rating of PH is based on Olaitan et al (1984) (see Appendix II).

4.1.1. Total Nitrogen

The average total nitrogen content for both terraced and non-terraced farm plots is rated low. There is relatively slight change of total nitrogen content within individual terraced and non-terraced plots as well as along a hill-slope position. This low value of total nitrogen could be due to the fact that the area is moist (not arid) and this may cause leaching of nitrogen in the soil. The other reason might be related to management problems in improving the nitrogen content by growing leguminous plants that fix nitrogen from the air through the nodules of their roots. As opposed to this reasoning, SCRP (2000) showed that various varieties
of beans (leguminous plants) are among the major crops that grow in the study area. Siriri et al (2005) noted that lower nitrogen values are recorded on the upper terrace section and moderately increases down the individual terrace. They related this appearance/condition with the higher bulk density and lower water conductivity that make most nutrients including nitrogen unavailable for crop uptake on the upper part of the considered terrace.

Terraced sites showed lower total nitrogen content than the non-terraced counter parts. This might be because of the concentration of water within terraces (especially at the lower section) that discourages the nitrifying bacteria by preventing the availability of oxygen within the soil. This could contribute to the slower decomposition of organic matter which is the main source of nitrogen. A relatively higher amount of total nitrogen on the non-terraced plots than on the terraced ones could be attributed to manuring or other soil management activities practiced by the respective farmers.
Table 6: Average Laboratory Results of Total Nitrogen, Organic Matter, Available Potassium, Available Phosphorus, PH, Cation Exchange Capacity and Texture of the Topsoil (0 -20cm) of the Farm Plots

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Location of the sample along a hill-slope position</th>
<th>Location of the sample within individual terraced plots</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upper</td>
<td>Middle</td>
<td>Lower</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upslope</td>
<td>Middle</td>
</tr>
<tr>
<td>Terraced</td>
<td></td>
<td>Upper</td>
<td>Middle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Middle</td>
<td>Lower</td>
</tr>
<tr>
<td>Down-slope</td>
<td></td>
<td>Upper</td>
<td>Middle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Middle</td>
<td>Lower</td>
</tr>
<tr>
<td>Non-terraced</td>
<td></td>
<td>Upper</td>
<td>Middle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Middle</td>
<td>Lower</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Down-slope</td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>0.13</td>
<td>1.39</td>
<td>6.2</td>
</tr>
<tr>
<td>Middle</td>
<td>0.12</td>
<td>1.7</td>
<td>8.22</td>
</tr>
<tr>
<td>Lower</td>
<td>0.15</td>
<td>2.07</td>
<td>8.02</td>
</tr>
<tr>
<td>Average</td>
<td>0.13</td>
<td>1.72</td>
<td>7.49</td>
</tr>
<tr>
<td>Upper</td>
<td>0.13</td>
<td>1.77</td>
<td>7.92</td>
</tr>
<tr>
<td>Middle</td>
<td>0.12</td>
<td>1.75</td>
<td>8.48</td>
</tr>
<tr>
<td>Lower</td>
<td>0.14</td>
<td>2.64</td>
<td>10.96</td>
</tr>
<tr>
<td>Average</td>
<td>0.13</td>
<td>2.05</td>
<td>9.12</td>
</tr>
<tr>
<td>Upper</td>
<td>0.15</td>
<td>2.31</td>
<td>8.95</td>
</tr>
<tr>
<td>Middle</td>
<td>0.14</td>
<td>2.07</td>
<td>8.6</td>
</tr>
<tr>
<td>Lower</td>
<td>0.13</td>
<td>3.17</td>
<td>14.18</td>
</tr>
<tr>
<td>Average</td>
<td>0.14</td>
<td>2.52</td>
<td>10.58</td>
</tr>
<tr>
<td>Upper</td>
<td>0.16</td>
<td>3.83</td>
<td>13.92</td>
</tr>
<tr>
<td>Middle</td>
<td>0.16</td>
<td>3.96</td>
<td>14.39</td>
</tr>
<tr>
<td>Lower</td>
<td>0.16</td>
<td>3.12</td>
<td>11.34</td>
</tr>
<tr>
<td>Average</td>
<td>0.16</td>
<td>3.64</td>
<td>13.22</td>
</tr>
<tr>
<td>Upper</td>
<td>0.16</td>
<td>3.29</td>
<td>11.95</td>
</tr>
<tr>
<td>Middle</td>
<td>0.14</td>
<td>2.45</td>
<td>10.17</td>
</tr>
<tr>
<td>Lower</td>
<td>0.15</td>
<td>3.78</td>
<td>14.65</td>
</tr>
<tr>
<td>Average</td>
<td>0.15</td>
<td>3.17</td>
<td>12.26</td>
</tr>
<tr>
<td>Upper</td>
<td>0.16</td>
<td>2.51</td>
<td>9.12</td>
</tr>
<tr>
<td>Middle</td>
<td>0.21</td>
<td>3.59</td>
<td>9.94</td>
</tr>
<tr>
<td>Lower</td>
<td>0.22</td>
<td>3.66</td>
<td>9.67</td>
</tr>
<tr>
<td>Average</td>
<td>0.2</td>
<td>3.25</td>
<td>9.58</td>
</tr>
</tbody>
</table>

4.1.2. Organic Matter*

The average organic matter value of terraced farm plots increases down a hill-slope position as well as relatively down individual terrace. This is in agreement with the perception of the sample farmers. They noted that

*Average organic matter = Average organic carbon x 1.72 (Landon, 1991)
the lower section of the terrace is usually more productive than the upper one. This might be due to the reason that the upper section has lower organic matter content than the lower section and such nutrient including others could also be washed away from the upper part of individual terrace and settle on the lower one. That is, the upper is erosional while the lower is depositional. Siriri et al (2005) found out that organic carbon decreased down the terrace, but a higher organic carbon content at the uphill than in the down hill.

All of the average values of organic matter of terraced and non-terraced farm plots are found very low. With some exceptions, the average organic matter content of non-terraced plots is lower indicating better value as compared to the amount in the terraced plots. This might be due to the soil fertility management practice conducted by the respective farmers.

4.1.3. Available Phosphorus

The average available phosphorus values of both terraced and non-terraced farm plots is recorded low. The values have no clear trend across a hill-slope position as well as within terraced and non-terraced plots, but it can be inferred from Table 6 that there is higher value at the lower terrace section. This might be caused by the availability of higher organic matter at this section (as shown in Table 6), which is the main source of organic phosphorus.

The mean available phosphorus taken from non-terraced plots is relatively better than the one from the terraced plots. This could be resulted in the better organic matter content of the non-terraced plots than the terraced ones that might be in turn attributed to the higher intensity of application of the soil management activities like manuring or compost (main sources of organic matter) by the owners of farm plots.
Glendinning (2000) asserted that in most soils, the amount of organic-P is highly correlated with the amount of organic-C; the rate of mineralization of organic-P increases as the organic-P content of the soil increases. That is, the more organic-P there is in the soil, the faster it is mineralized to be converted into available forms for plants' uptake.

The overall inadequacy of available phosphorus on both considered farm plots could be due to the following factors:

- Texture of the soil: As the laboratory analysis revealed, the texture of the sampled soils is clay. This could restrict aeration which is essential for micro organisms living in the soil to breakdown organic matter.
- Parent material: The low record of available phosphorus content might be because of the reason that the parent material in which the considered soils are derived could be poor in minerals containing phosphorus.
- Erosion: Gete (2000) mentioned the presence of higher storms in June, July & August and poor land management factor that causes severe soil erosion in Dembecha area (including Minchbet catchment). This condition could also lead to the removal of available phosphorus including other nutrients from the top soil.

### 4.1.4 Available Potassium

With some exceptions, the average available potassium content of both the terraced and the non-terrace farm plots is found high. It increases down the individual terrace and hill-slope position. There is also almost constant value of available potassium within non-terraced plots and along hill-slope position.

The occurrence of high rates of mean available potassium in both considered farm plots could be attributed to the very high values of CEC
of the sampled soils which indicate their greater storage capacity and supplying power for potassium. Glendinning (2000) asserted that soils of low CEC have little ability to store potassium and large applications of this element are likely to be used very inefficiently by the plant and lost by leaching. Soil colloids (very small soil particles) have negative charges and attract cations, such as potassium. Soil colloids repel anions, such as nitrate. So, cations are held in exchangeable form (adsorbed) to be readily available for plants' uptake. The second reason might be related to the parent material from which the soil is derived. In chapter 3 of this thesis, it was shown that the geology of the study area belongs to the basaltic Trapp series of the Tertiary volcanic eruptions. In connection with this, Olaitan et al (1984) explained that compared with other nutrients the amounts of potassium in soils are usually high, especially in newly opened fallows or in soils derived from basement complexes (metamorphosed rocks) or volcanic ash.

4.1.5 PH

The mean PH value of both the terraced and the non-terraced farm plots is rated moderately acidic. This might be resulted due to the moist condition prevailing in the study area (as mentioned above). As excess rainfall passes through the soil, there could be leaching of basic nutrients like calcium and magnesium. Thus, these nutrients will be replaced by acidic elements including hydrogen and aluminum. Because of such condition, there will be an increase in the acidity of the soils (Olaitan et al, 1984; Glendinning, 2000). The other reason could be related to the parent material of the sampled soils. The Trapp series also include rare rhyolites. Olaitan et al (1984) and Glendinning (2000) explained that soils developed from acidic rocks (parent materials) such as granite and rhyolite contain an excess of quartz or silica and these, combined with various proportions of water, form acids such as silicic
acid, and trisilicic acid. Hence, soils developed from acid rocks have lower PH value than those developed from basic rocks.

### 4.1.6 CEC

Some of the CEC values of the soils sampled from both terraced and non-terraced farm plots are found very high while some are high (see Table 6). The laboratory analysis of the sampled soils indicated that their texture is more of clay. These finer soils are negatively-charged particles. For this reason, they can attract, hold and release positively charged nutrient particles (cations). Sand particles carry little or no charge and do not reach. Thus, a high clay soils can hold more exchangeable cations than a low clay soils (Glendinning, 2000). Gete (2000) reported a high CEC of the soils in Anjeni, and he indicated the high clay content of the soils as a probable reason for this.

### 4.1.7 Texture

As can be seen from Table 6, the average textural class of both terraced and non-terraced farm plots is more of clay. The laboratory analysis indicated that soils sampled from the middle of the individual terrace as well as from the middle slope of the terraced sites have a clay loam textural class. Clay loam contains a higher proportion of clay and relatively lower amounts of sand and silt. This is relatively good for plants than clay since it has more open spaces that encourage aeration and more water to be readily available for plants’ use. Glendinning (2000) noted that clay soils have good water holding capacity. However, they hold such water so tightly that it is not easily available for plants.

### 4.2. Construction, Maintenance, Benefits and Problems of Terraces

#### 4.2.1. Features of Terraced and Non-terraced Farm Plots

Due to increased population pressure, farmers in the highlands of Ethiopia in general and those in the study area in particular are facing fragmentation and shortage of farm plots.
The results of the questionnaire survey revealed that 72% of the sample households indicated that their farm plots are far apart, where as those whose farm plots are near each other account only for 5%. The more the plots are fragmented, the less the farmers could have time and energy to take care of their plots. This implies that land fragmentation minimizes the probability of properly conserving untreated plots and maintaining terraced ones.

Table 7: Number of Farm Plots of Household Heads

<table>
<thead>
<tr>
<th>No of Plots</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Field Survey, 2007

Table 7 indicates that 30% of the households, which is the highest of all, do have 4 plots. Those who possess only 1 and 2 plots account for 2%. Increased number of plots is a manifestation of the presence of land fragmentation.

Moreover, the size of a particular plot the farmers cultivate is very small. The maximum size recorded is 1.25ha while the minimum size is only

Note: The informants responded the size of their farm plots in “Timad”. Hence, this is converted into hectare by dividing it with 4.
0.06ha. The maximum plot size of the 27% of households is only 0.5ha while the minimum plot size, 60% of the respondents, cultivate is only 0.125ha.

Table 8: Total Farm Size of Household Heads

<table>
<thead>
<tr>
<th>Total Farm size (ha)</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25 - 1</td>
<td>14</td>
<td>28</td>
</tr>
<tr>
<td>1.01 - 1.75</td>
<td>28</td>
<td>56</td>
</tr>
<tr>
<td>1.76 - 2.5</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>2.51 - 3.25</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Field Survey, 2007

As can be seen from Table 8, 56% of the household heads' total farm size, which is the maximum, ranges from 1.01 ha to 1.75 ha. The minimum number of them, that is 20%, does have a total farm size ranging from 2.51 ha to 3.25 ha. According to Ludi (2004), per capita land holdings in Anjeni area decreased from 2.95 ha in 1986 to 2.1 ha in 1998/1999.

4.2.2. Construction of Terraces

The study area, Anjeni area, experienced extensive construction of graded fanya juu bunds (or terraces) in 1985 outside the SWC research catchment and from February to April 1986 inside the catchment. This was accomplished not through the food-for-work programme, but through the offering of clinic as a social incentive (Ludi, 2004). During this time, farmers were obliged to participate the campaign by the government (or by the then Chairman of Anjeni PA). Besides, farmers
were not aware of the ability of graded fanya juu bunds in conserving soil and water.

Hence, so as to identify farmers' change of awareness, they were asked whether they incorporated such bunds for their farm plots, which are found outside the research catchment through their interest or not. The survey revealed that 47 sample household heads were interested. Only one female farmer responded that she constructed the terrace coerced by the government.

The farmers mentioned that their plots located outside the research catchment were conserved with terraces using their own family labour source and using campaign organized by the local Agricultural Office.

Table 9: Farmers’ Sources of Information on the Construction of Terraces

<table>
<thead>
<tr>
<th>Sources of Information</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own Experience</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>DA (or any SWC expert)</td>
<td>42</td>
<td>84</td>
</tr>
<tr>
<td>Neighbour(s)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Field Survey, 2007

As can be seen from Table 9, 84% of the farmers obtained the information from the DAs (or any SWC experts), 7% from own experience and 2% from neighbour(s).

To sum up, it is observed during the field survey that because it reduced severe soil erosion problem, construction of terrace is rapidly increasing in the study area.
4.2.3. Effects of Terraces on Erosion

Soil erosion happens when the soil becomes loose and carried away by water or wind. When there is heavy rainfall, water can not seep into the soil fast enough. Thus, the extra water (runoff) flows down slope carrying large amounts of soil particles with it. The erosion problem is likely to be severe on certain types of soils, on steep slopes, where there is intense rainfall, where the vegetation is removed, and where there is no appropriate conservation measure in place.

Therefore, one way of checking the effectiveness (appropriateness) of conservation measures in reducing soil erosion is by exploring the opinion of the users. The opinion of interviewed farmers on the effect of terraces on erosion is presented below.

Conditions of Erosion Before and After the Introduction of Terrace

Of the interviewed farmers, 94% confirmed that the rate of soil erosion before the introduction of terraces on their plots was severe and only 6% said that it was moderate (see Table 10).

Table 10: Farmers' Opinions on the Rate of Soil Erosion Before the Introduction of Terraces

<table>
<thead>
<tr>
<th>Rate of Soil Erosion</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No soil erosion</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Slight soil erosion</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Moderate soil erosion</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Severe soil erosion</td>
<td>47</td>
<td>94</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Field Survey, 2007
The impact of conservation measures including terraces is largely reducing soil erosion; it is difficult to absolutely stop soil erosion. Even in areas that receive high amount of rainfall, there can be excessive flooding from terraces. This makes it difficult for the farmers to realize the full benefits of conservation.

The result of the questionnaire survey indicated that 92% (46 out of 50) respondents agreed with the presence of soil erosion problem under their field now treated with terrace. Out of 46 respondents, 44 of them rated the status of soil erosion after the introduction of terraces to their farm plots as slight (see Table 11).

Table 11: Farmers’ Opinions on the Rate of Soil Erosion After the Introduction of Terraces

<table>
<thead>
<tr>
<th>Rate of Soil Erosion</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slight erosion</td>
<td>44</td>
<td>95.65</td>
</tr>
<tr>
<td>Moderate erosion</td>
<td>2</td>
<td>4.35</td>
</tr>
<tr>
<td>Severe erosion</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>46</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Field Survey, 2007

Soil erosion is the down slope movement of soil because of the effect of runoff or wind. Hence, the upper part of either the hill-slope or the inter-terrace area losses much more soil than the lower counterpart. Forty-one out of 46 farmers said that soil erosion process is severe (higher) at the upper section of the terrace. The remaining 5 of them noted such process to be higher at the middle of the cultivated field. Some farmers pointed out that they noticed crop yield difference between upper and lower terrace sections. They said that the lower is more productive than the upper. This idea is similar to the study by Siriri et al (2005). They
stated that terrace benches on the hill-slopes of Western Uganda exhibit a crop-yield gradient both within individual terraces and along hill-slope positions.

**Extent of Soil Erosion in Anjeni Area Based on SCRP Data**

**Experimental Plot Data Results**

The runoff and soil loss data of the experimental plots treated with different conservation measures indicates lower value as compared to the control (untreated) plot.

Table 12: Mean Annual Runoff and Soil Loss

<table>
<thead>
<tr>
<th>Year</th>
<th>Runoff (% of Control Plot)</th>
<th>Soil Loss (% of Control Plot)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Plot</td>
<td>Grass Strip</td>
</tr>
<tr>
<td>1986</td>
<td>100</td>
<td>67.92</td>
</tr>
<tr>
<td>1987</td>
<td>100</td>
<td>74.38</td>
</tr>
<tr>
<td>1988</td>
<td>100</td>
<td>58.56</td>
</tr>
<tr>
<td>1989</td>
<td>100</td>
<td>61.34</td>
</tr>
<tr>
<td>1990</td>
<td>100</td>
<td>52.32</td>
</tr>
<tr>
<td>1992</td>
<td>100</td>
<td>64.30</td>
</tr>
<tr>
<td>% of control plot (mean 1)</td>
<td>100</td>
<td>66.71</td>
</tr>
<tr>
<td>% of control plot (mean 2)</td>
<td>100</td>
<td>59.23</td>
</tr>
</tbody>
</table>

**Remarks:**
- The slope and soil type of all experimental plots are 28% and Vertic Luvisol respectively.
- Mean 1: 1986 - 1990, only control plot, graded fanya juu, graded bund.
- 1991: No data because of war.


As it is shown above, there is no significant difference between graded fanya juu and graded bund in the mean annual runoff and soil loss.
Even if grass strip is introduced lately that makes comparison difficult, the mean runoff and soil loss value is lower as compared to the graded fanya juu and graded bund. In general, the treated plots perform better than the control plot in reducing runoff and soil loss.

Table 13: Mean Annual Runoff and Soil Loss

<table>
<thead>
<tr>
<th>Year</th>
<th>Runoff (% of Control Plot)</th>
<th>Soil Loss (% of Control Plot)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Plot</td>
<td>Grass Strip</td>
</tr>
<tr>
<td>1986</td>
<td>100</td>
<td>97.81</td>
</tr>
<tr>
<td>1987</td>
<td>100</td>
<td>91.80</td>
</tr>
<tr>
<td>1988</td>
<td>100</td>
<td>45.87</td>
</tr>
<tr>
<td>1989</td>
<td>100</td>
<td>43.75</td>
</tr>
<tr>
<td>1990</td>
<td>100</td>
<td>65.16</td>
</tr>
<tr>
<td>% of control plot (mean 1)</td>
<td>100</td>
<td>49.62</td>
</tr>
<tr>
<td>% of control plot (mean 2)</td>
<td>100</td>
<td>81.44</td>
</tr>
</tbody>
</table>

Remarks:
- The slope and soil type of the experimental plots are 12% and Eutric Nitosol respectively.
- Mean 1: 1986 - 1990, only control, graded fanya juu and graded bund.
- Mean 2: 1986 - 1990, all plots, if all 4 plots have the same crop.
- 1991: No data because of war.


As can be seen from Table 13, there is significant difference among grass strip, graded fanya juu and graded bund. Both the mean runoff and soil loss are lower on graded fanya juu. Grass strip allows more runoff to pass. In general, the treated plots showed better performance in fighting against runoff and soil loss than the control plot.
**Hydrometric Station Results**

As can be shown in the Table 14, the suspended sediment yield other than the discharge yield was reduced from time to time. The discharge yield did not show significant difference among the different years.

<table>
<thead>
<tr>
<th>Year</th>
<th>Discharge (mm)</th>
<th>Suspended Yield (t/ha)</th>
<th>Sediment Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>(656.6)</td>
<td>(31.22)</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>755.1</td>
<td>61.55</td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>682</td>
<td>23.54</td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>756.4</td>
<td>16.48</td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>779</td>
<td>6.32</td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>610.7</td>
<td>5.85</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>750.4</td>
<td>32.95</td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>657.3</td>
<td>23.22</td>
<td></td>
</tr>
<tr>
<td>1992</td>
<td>720.7</td>
<td>18.87</td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>867</td>
<td>32.28</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>731</td>
<td>25.23</td>
<td></td>
</tr>
<tr>
<td>STD</td>
<td>74</td>
<td>16.06</td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td>10.2</td>
<td>63.7</td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td>867</td>
<td>61.55</td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>610.7</td>
<td>5.85</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** The data collection for 1984 has been started since June.

Source: SCRP database (1984 - 1993), first draft

As a whole, from the Tables 12, 13 and 14, it is possible to conclude that the runoff and soil loss value were reduced after the introduction terraces in the catchment. In other words, keeping other factors constant, conserved fields with appropriate measures are expected to reduce soil erosion.
**Causes of Erosion**

In his day-to-day activities, man has caused soil erosion problems. His interaction with the natural environment resulted in the loss of precious topsoil that contains important minerals for plant growth which could reduce the ability of the land to support the increasing pressure of population. However, it is clear that the extent and factors of erosion varies with time and place.

Table 15: Farmers’ Opinions on the Causes of Soil Erosion on their Farm Plots

<table>
<thead>
<tr>
<th>Causes of Erosion</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steepness of the field</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>Intensive cultivation</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Heavy rainfall</td>
<td>19</td>
<td>38</td>
</tr>
<tr>
<td>Deforestation</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>Overgrazing</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Up and down ploughing</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>Roads or foot paths that cross farmlands as agent of concentrating water</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>All of the above</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Note:**  - Other denotes weakness in digging waterways (drainage ditches).
- The percentage adds up to more than 100 because of double responses.
Source: Field Survey, 2007
As can be inferred from Table 15, heavy rainfall, steepness of the field and deforestation are perceived to be the major causes of erosion on their farm plots. Indeed, $1/5^{th}$ of the household heads believed that all of the above-mentioned alternatives are the major causes of erosion. Only 9 out of the total sample of farmers noted a single factor of erosion. This indicates that most of them have got an understanding that soil erosion is caused by combined factors. In support of this idea, Taffa (2002) explained in his book that land degradation is initiated by both human activities and natural hazards.

**Impacts of Erosion**

The impacts of erosion are both on-site and off-site. The on-site effects include decline in the content of soil nutrients, water holding capacity and fertility problems, tillage difficulties, etc. This leads to the reduction of productivity of the soils. On the other hand, the off-site effects include flooding, reduction in water quality, increase in suspended sediment and the like on the down slope side.

According to the result of the questionnaire survey which emphasizes only on the on-site impacts, all of the farmers pointed out that the impacts of erosion on their fields are loss of soil fertility, loss of soil and reduction in crop yield.

**4.2.4. Supportive Conservation Measures**

Despite the fact that terraces are good in conserving soil and water, farmers asserted that it is not possible to conclude that soil erosion is fully controlled after their field is conserved with terrace. Thus, in order to mitigate the problem of soil erosion and to maintain the fertility of the soil, they said that they are using other supportive conservation measures.
From the above perception of farmers we can infer that terraces can be effective if and only if they are used in combination with other conservation measures. To be effective, it has to be combined with proper agronomic and vegetative measures like hedgerows, strip cropping, and contouring (Dorren and Rey, 2004; Daniel, 2005).

The supportive conservation practices that the farmers listed are presented below.

- **Manure Application:** The interviewed farmers described that they are incorporating mostly animal manure to their farm plots because they think that terraces alone can't control soil erosion. Most of them said that they are using such soil fertility management measure around their homestead because of the lack of availability of manures and their plots are so fragmented. However, a few of them noted that they also employ such measure outside their homestead.

- **Compost Application:** Some of the surveyed farmers said that they are preparing compost occasionally even though they know that it is important in maintaining soil fertility. Their reason was that compost preparation is tiresome. This can be assured by the fact that all of them, who noted that they have been preparing compost, are not old-aged. That is, since preparation of compost is labour-intensive, it discourages farmers especially old-aged ones not incorporate it.

- **Drainage Ditches:** Farmers mentioned that they have been digging drainage ditches every cropping season diagonally as well as on some parts of the farm plot in order to minimize the concentration of water upon the lower section of the terrace. They said that such
concentration if it is not drained immediately, it can cause a disease for barley called "Wag" (a fungal plant disease that mainly affect leaves). They added that if the sown crop is teff, they have to dig more ditches. For doing so, they reasoned out that since the stalk of teff is weak, such concentration of water can threaten it.

- **Cut-off Drains:** Most of the interviewed farmers pointed out that they try to reduce the problem of runoff by constructing such structure at the upper end of the terrace.

- **Waterways:** In the field survey, it was observed that waterways are well-established inside the Minchet catchment than outside of it. However, some of them are widened and changed into gullies. In the Minchet catchment, it was also observed that the waterways are constructed on both sides of each farm.

- **Check Dams:** Some of the interviewed farmers said that they have been using such barriers to prevent the effect of runoff. They noted that they are preparing check dams using stones, plant materials and sometimes using sacks filled with soils. During the field survey, it was observed that there are big gullies both inside and outside the Minchet catchment. Farmers attempt in protecting such gullies is minimal. This is because the gully is still widening and encroaching the nearby foot paths. They simply planted trees and bushes inside and along the big gullies.

- **Horizontal (Contour) Ploughing:** Farmers mentioned that they are employing such kind of farming practice to minimize the problem of soil erosion on their farm plots conserved with terrace.
➢ Tree and Grass Plantation: Some farmers asserted that to assist the terrace in fighting against soil erosion, they have been planting like “Girawa” (Vernonia amygdalian), “Bisana” (Croton macrostachyus), Susbania (Susbania susban) and Elephant grass (Pennisetum purpureum). They also said that they encourage the growth of natural grass up on the lower most end of the terrace (terrace riser).

➢ Crop Rotation: Farmers expressed that teff is responsible for higher soil erosion on their farm plots. Thus, it has to be rotated to minimize this problem. Some of them mentioned that a cereal has to be followed by pulses.

➢ Mixed Cropping: Some farmers said that they are incorporating maize, potato and "Gomen Zer" (oil seed) to enhance the soil fertility of their farm plots treated with terraces.

➢ Mulching: A few farmers indicated that to prevent the problem of soil erosion on their farm plots conserved with terraces they have been covering their plots with straw (hay).

➢ Fallowing: Only one informant mentioned that he has been undertaking fallowing to minimize the problem of soil erosion in his terraced farm plot. This almost nil adoption of fallowing can be attributed to the problem of land shortage in the study area.

4.2.5. Proportion of Terraced and Non-terraced Farm Plots

Even if terracing is criticized by its inefficiency in controlling the detachment of soil particles and by its expensiveness in initial installation and maintenance, the questionnaire survey revealed that the
proportion of terraced farm plots is much higher than the non-terraced farm plots. All of the surveyed household heads (50 of them) indicated that one or more of their plot is terraced. The number of respondents whose farm fragments are totally terraced is 32 while 18 of them said that one or more of their plot is terraced (see Table 16).

Table 16: The Proportion of Non-terraced Farm Plots of the 18 Household Heads in Comparison with the Total Number of Plots Owned

<table>
<thead>
<tr>
<th>No of Plots</th>
<th>Proportion of Non-terraced Plot(s)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>18</td>
</tr>
</tbody>
</table>

Source: Field Survey, 2007

The high proportion of plots covered by terrace can be explained by the satisfactory adoption of graded fanya juu bunds, which were introduced in 1985 and 1986 in the study area by SCRP. However, during these periods, farmers were participating in the campaign unwillingly. It is through time when farmers realized the importance of such introduced bunds that they started to conduct widespread construction. From this, we can infer that the adoption of terrace depends on farmers' knowledge or attitude.

There were other conservation measures that the farmers have been employing for non-terraced plots. These include contour cultivation, drainage ditches and waterways, manuring, crop rotation, and mixed
cropping. The probability of adopting one or more of such measures depends on farmers' skills or attitude, position of plots on the slope, plots closeness to home, availability of labour, soil characteristics, climate of the area, farm size and so on.

4.2.6. **Comparison of Terraced and Non-terraced Farm Plots**

Most researchers investigated that the amount of runoff and soil loss from terraced fields is lower than the non-terraced ones. The crop yield result given by Solomon (1994) indicates that the amount from plots treated with graded fanya juu (dominant in the study area) was more or less increasing from year to year as compared to the control plot.

The opinion of informants, who are purposefully selected, on the comparison of their terraced farm plots in the Minchet catchment and non-terraced ones outside the catchment is given below.

*Based on Fertility*
Farmers (10% of the total) asserted that their terraced farm plots are more fertile than the non-terraced ones since the latter are more prone to soil erosion than the former. This is true because if the non-terraced one is not treated with other appropriate conservation measures, it will loose its fertile topsoil which comprises important minerals and organic matter by erosion.

*Based on Susceptibility to Erosion*
The non-terraced farm plots are more susceptible to soil erosion than the terraced ones as farmers mentioned. They added that their susceptibility rises if they are not at least treated with drainage ditches or waterways, if there is heavy rainfall, and it rises with the steepness of the field. This does not mean that terraces alone are effective in controlling soil erosion.
However, supportive conservation techniques are employed by farmers in fighting against erosion (as given above).

**Based on Yield**

The terraced farm plots are more productive than the non-terraced ones as the respondents noted. They said that its productivity varies with soil type, the amount of manuring, and the position of a plot on the slope. One farmer roughly estimated that if we obtain 4 quintals of a given crop from the non-terraced plot, the corresponding amount that we can have from the terraced one is 5 quintals.

The SCRP database (1984 - 1993) indicated that the experimental plots, which were treated with graded fanya juu and graded grass strip and considering the years only when the plots were planted with the same crop in each set, the results of crop yield (both grain and biomass) were higher for these treated plots on the 28% and 12% slopes as compared to that of the control plot. The grain yield increase varies from about 14% to 15% on the 12% slope and from 0% to 2% on the 28% slope.

**4.2.7. Maintenance of Terraces**

All farmers except one said that they have been maintaining their terraced farm plots. This farmer, who doesn’t maintain his terraced plot until now, forwarded that "since I was warned by the local Agricultural Officers during the fanya juu construction campaign that was held in 1986 not to disturb the terrace, I had never maintained my terraced plot." Regardless of this farmer’s perception, we can say that almost all of the respondents are aware of the importance of terrace maintenance.
**Frequency and Ways of Maintenance**

Some farmers revealed that they maintain their terraced farm plot annually before the beginning of the big rain. Others said that they undertake such action if and only if there is damaged terraced bund.

Farmers' practices in maintaining terraces include stabilizing the terrace bund by leaving the riser slope with grass cover (elephant grass or by encouraging naturally grown grasses), redeveloping the terrace bunds, digging drainage ditches across plots, planting bushes or trees along the terrace bunds (trees like "Girawa", "Bisana" and Susbania or by encouraging naturally grown trees), and stabilizing the damaged terrace bunds with stone and soil (see table below).

Table 17: Practices used by the Farmers to Maintain Terraces

<table>
<thead>
<tr>
<th>Practice</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stabilizing the terrace bund by leaving the riser slope with grass cover</td>
<td>31</td>
<td>62</td>
</tr>
<tr>
<td>Redeveloping the terrace bunds</td>
<td>39</td>
<td>78</td>
</tr>
<tr>
<td>Digging drainage ditches across plots</td>
<td>13</td>
<td>26</td>
</tr>
<tr>
<td>Planting bushes or trees along the terrace bunds</td>
<td>21</td>
<td>42</td>
</tr>
<tr>
<td>Stabilizing the damaged terrace bunds with stone and soil</td>
<td>34</td>
<td>68</td>
</tr>
</tbody>
</table>

**Note:** The percentage adds up to more than 100% because of multiple responses.

Source: Field Survey, 2007

Most of the practices in terrace maintenance employed by the household heads are aimed at stabilizing and redeveloping the terrace bunds. This is because they are more prone to soil erosion than the terrace benches. They are responsible for trapping sediments carrying important nutrients that are coming from the upper section of a particular terrace. The
practice which is concerned with protecting the cultivable terrace bench from soil erosion is digging drainage ditches across plots. It also improves soil fertility since it discourages low infiltration and the release of nutrients.

**Sources of Labour for Maintenance**

Terraces can reduce soil erosion if they are correctly constructed and maintained. Most literatures state that terraces require larger labour and capital investment. The result of the questionnaire survey also confirms that the main source of labour for maintenance of terraces is family labour followed by father labour (see Table 18). From this, we can deduce that most of the time terrace maintenance requires group labour rather than individual labour.

Table 18: Sources of Labour for Maintaining Terraced Farm Plots of the Respondents

<table>
<thead>
<tr>
<th>Person</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Father</td>
<td>16</td>
<td>32.65</td>
</tr>
<tr>
<td>Mother</td>
<td>1</td>
<td>2.04</td>
</tr>
<tr>
<td>Family</td>
<td>31</td>
<td>63.27</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>2.04</td>
</tr>
<tr>
<td>Total</td>
<td>49</td>
<td>100</td>
</tr>
</tbody>
</table>

*Note:* ‘Other’ refers to father and hired labour.

Source: Field Survey, 2007

In an attempt to assess farmers' interest on help for maintenance of terraces, it is found out that their main problem that hinder such action is the lack of farming implements like shovel and pickaxe. Some also showed their wants on expert advice, labour and sack (i.e. if it is filled with soil, it could function to maintain the damaged terrace bunds).
Therefore, farmer’s problem in connection with maintenance of terraces is not labour, but it is the lack of access to farming implements.

**4.2.8. Destruction of Terraces**

Half of the respondents had ever destroyed the terrace bench, while the remaining half of them had never. Farmers especially those that have farm plots in Minchel catchment revealed that they destroyed the terrace bench after it was constructed by the campaign because of the narrowing of cropland which in turn makes farming difficult. Others said that they destroyed the terrace bench when it becomes big to distribute the fertile soils accumulated at the terrace bund all over the plot by constructing another at the place where it is highly eroded.

Scholars advice that it is not important to destroy the terrace bench and construct another one in search of fertile soils. They added that it would be better to redevelop the existing terraces and supporting them with other soil fertility and SWC measures such as use of compost, farmyard manure, improved fallows and use of grass strips in areas which are intensively cultivated, with high population density and high levels of land fragmentation.

Seventy percent of the respondents mentioned that they had ever vertically dug the terrace riser, while the remaining 30% had never. Farmers noted that they did so to avail more land for farming, to destroy rodents' caves, to ease farming since oxen don’t want to approach the highly elevated terrace risers, and in search of fertile soils to distribute all over the terrace bench. In relation to this, Aklilu and De Graaff (2006) reported that “Erken Meshar” (literally means terrace destruction) is an indigenous practice which farmers of Beresa watershed in the central highlands of Ethiopia use to improve the effectiveness of stone terraces.
They added that it is used to redistribute entrapped soil at the edge of the terraces and to reduce rodent breeding.

Table 19: Farmers’ Reasons for Vertically Digging Terrace Risers

<table>
<thead>
<tr>
<th>Reason</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>To avail more land for farming</td>
<td>24</td>
<td>68.57</td>
</tr>
<tr>
<td>Since oxen don't approach the highly elevated terrace risers</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>To destroy rodents’ caves</td>
<td>3</td>
<td>8.57</td>
</tr>
<tr>
<td>In search of fertile soils</td>
<td>6</td>
<td>17.14</td>
</tr>
</tbody>
</table>

**Note:**
- The total number of respondents who replied for this question is 35.
- The percentage adds up to more than 100 because of multiple responses.

Source: Field Survey, 2007

As can be seen from Table 19, most farmers vertically dug the terrace risers to avail more land for farming. They said that when the risers become big it makes the cropland narrower and it also allows weeds to cover the farm. In this case, they will be subjected to dig the risers. On the other hand, other farmers argued that they had never dug the risers since the grass that grows on them is important for their oxen. This practice of digging may lead the terrace bench to be unstable and to be more prone to soil erosion since inappropriate break may lead to the crops (nutrients) being easily washed away.

4.2.9. The Future of Terraces and Terrace Use in Anjeni

All of the surveyed farmers asserted that they are strongly interested to continue by incorporating terraces up on their farm plots. All except one
reasoned out that the productivity of their terraced plots is increasing from time to time. Farmers forwarded their sayings which reflect their strong interest on terraces as "if somebody tried to destroy my terraced plots at all, I don't allow him to do so and I rather choose to be imprisoned", "if terraces were not introduced in Anjeni, let alone crops, grasses did not grow", "nobody would live in Anjeni if terraces were not introduced", "teff started to grow only after the introduction of terraces" and the like.

The above sayings of respondents depict that they are satisfied with the capability of terraces in SWC as compared to the previous years in which terraces (fanya juu bunds) were not introduced.

4.2.10. Benefits of Terraces
Most researchers criticize that terraces are not good in preventing detachment of soil particles, but they confirm that they are effective in reducing transport of soil particles. Thus, they advice to employ terraces in combination with vegetative or agronomic measures. Farmers forwarded their opinions on the benefits of terraces as follows.
Table 20: Farmer’s Opinions on the Benefits of Terraces

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Having less rills on the cropland and hence less erosion of seedlings</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Increase in soil fertility by conserving soil</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Increase in soil moisture by conserving water</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Increase in yield</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>All of the above</td>
<td>48</td>
<td>96</td>
</tr>
<tr>
<td>Grasses grown on terrace risers are important for oxen</td>
<td>6</td>
<td>12</td>
</tr>
</tbody>
</table>

**Note:**
- The total number of respondents is 50.
- The percentage adds up to more than 100 because of double responses.

Source: Field survey, 2007

As it is shown in Table 20, most farmers noted that they have gained all of the first four benefits of terraces after the introduction of them on their plots. Keirle (2000) generalized the functions of terraces into two:

1) They reduce the slope length, shortening it to the distance between one terrace and the next, since water from the next terrace uphill is either retained to infiltrate into the soil or drained off sideways to a waterway.

2) Most terraces are constructed so that the slope from the front to the back of the terrace itself is reduced.

4.2.11. Problems of Terraces

Although there had been tremendous efforts on SWC in Africa including Ethiopia, land degradation is still escalating from time to time. This can be attributed to the inappropriateness of conservation measures, inefficiency of experts, lack of awareness of farmers, land tenure
relationships and the like. Farmers' perception on problems of terraces is given below.

Table 21: Farmers' Perceptions on Problems of Terraces

<table>
<thead>
<tr>
<th>Problem</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>The terrace is too narrow making farming difficult</td>
<td>18</td>
<td>36</td>
</tr>
<tr>
<td>The vertical waterway which develops into gullies</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Overflow of runoff during heavy storms</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Require larger labour and financial investment</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>All of the above</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Other</td>
<td>25</td>
<td>50</td>
</tr>
</tbody>
</table>

*Note:*
- 'Other' denotes the terrace bund is hiding place for rodents, there is usually concentration of water at the lower section of the terrace which brings a plant disease called "Wag" for barley, the upper section of the terrace losses its moisture easily while the lower one has excessive moisture, the oxen don't want to approach the upper and lower most end of terrace bunds, it is not favourable to dig drainage ditches across terrace benches, and it has no problem at all.
- The percentage adds up to more than 100 because of double responses.

Source: Field Survey, 2007

As Table 21 revealed, half of the respondents showed that the problems of terraces are included under the alternative 'other' while 36% of them said that the problem of terrace is related to its narrowness which makes farming difficult. In order to reduce the cited limitations of terraces, it is advisable to employ supportive conservation measures. This is because the problem of terraces can be overcomed by its complements.
In the previous sections, it is shown that construction of terraces is widely practiced in the study area. On the contrary, Yohannes (1999) in his evaluation of graded fanya juu in Andit Tid catchment indicates that only 17% of the structures remained intact, while on 53% of the plots in the catchment the technology was totally rejected. The fundamental factor for its rejection was the wider risks attached to land, it demands high labour for construction and maintenance, it creates water-logging problems, which affect crop yields, and it also creates artificial waterways, which developed into bigger gullies.
CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

SWC measures like terraces play a key role for the sustainable use of resources in general and for reduction of soil erosion in particular. The study area experienced a widespread construction of terraces in the mid 1980s by the major pull factor of the drought of 1972/73 that initiated SWC in the drought affected areas of Ethiopia.

The effect of terraces on soil properties/fertility varies with the ways of construction and maintenance. Results of the soil laboratory analysis of revealed that the mean total nitrogen, organic matter, available phosphorus contents of the terraced farm plots are relatively lower than the non–terraced counterparts. This might be because of the effect of soil management measures taken by the farmers. The other reason could be related to the concentration of water at the lower section of terraces that discourage nitrifying bacteria not to decompose organic matter in an expectable manner.

It was also found higher mean values of available potassium and CEC on both terraced and non-terraced farm plots. This could be due to the occurrence of clays (negatively charged) on the sampled plots that attract, hold or release cations. On the other hand, the PH is found acidic which could be resulted due to the moist condition of the area and the parent material of the sampled soils.

The status of soil erosion problem before and after the introduction of terrace in the study area is rated as severe and slight by the respondents. It was also shown that this problem as opposed to
productivity decreases down individual terrace. The informants also said that erosion is caused by the combined factors.

None of the interviewed farmers indicated that they have no terraced farm plots. Moreover, they depicted that the susceptibility to erosion of the terraced plots is lower than the non-terraced ones.

The questionnaire survey revealed that the maintenance of terraces which emphasize mainly on terrace bunds include stabilizing the terrace bund by leaving the riser slope with grass cover, redeveloping the terrace bunds, planting bushes or trees along the terrace bunds, and stabilizing the damaged terrace bunds with stone and soil. On the other hand, the practice which is concerned with maintaining terrace benches is digging drainage ditches across farm plots.

Half of the respondents experienced the destruction of terrace benches while 70 % of them had ever dug the riser of their terraced farm plots to avail more land for farming and to distribute the fertile soils accumulated at the bund all over the cultivable land.

The surveyed farmers showed their future interest on the adoption of terraces for the fact that the productivity of their terraced farm plots is increasing from time to time. On the contrary, the laboratory results of selected soil parameters of non–terraced plots are better than the terraced ones. Perhaps this could be attributed to the extent of treatment of the non–terraced plots by the respective farmers might be better than the extent experienced by terraced ones. That is, nutrients need to be recycled after harvesting in the form of crop residues/manuring and the like.
The benefits of terraces listed by most farmers include having less rills on the cropland and hence less erosion of seedlings, increase in soil fertility by conserving soil, increase in soil moisture by conserving water, and increase in yield. They also noted the major problems of terraces which include the terrace is too narrow making farming difficult, the terrace bund is hiding place for rodents, concentration of water at the lower terrace section which bring a plant disease called “Wag” for barley, moisture is higher at the lower section than the upper counterpart, not favourable for having drainage ditches across terraced farm plots, and the terrace risers prevent the oxen not to plough going up to the lower and upper most end of individual terraces. Some also showed that terraces have no problem at all.

In general, the study found two contradictory results: 1) the laboratory analysis revealed that the soil condition, measured by the various soil physical and chemical properties, is relatively better on the non–terraced farm plots than on the terraced ones, and 2) assessment of farmers’ opinion indicated that the soil condition in relation to productivity is relatively better on terraced farm plots than on the non–terraced ones. However, although the soil samples are small, they are collected following a standard procedure. Thus, the reliability of mainly the farmers’ opinion is doubtful which needs further research.

5.2 Recommendations
Based on the findings of this study, the following recommendations are forwarded:

- Even though terraced farm plots of Minchert catchment are well–developed, the laboratory analysis of selected soil parameters (including NPK) indicated lower value as compared to the non–terraced farm plots. In order to improve such problem, farmers have to be advised to increase the rate of complimenting the
terraced plots with appropriate conservation measures. That means the rate of, for example, manuring, compost application and the like have to be escalated to improve soil fertility.

- The terraced plots outside the Minchet catchment are not well-structured. Hence, experts mainly experienced agricultural officers as well as farmers have to participate in planning and constructing terraces for the effective control of soil erosion. That is, for removing runoff in a safe manner by constructing appropriate waterways, cut-off drains as well as by constructing terrace with reference to the contour.

- Terraces require long time to enhance soil fertility/productivity after they are installed. Thus, farmers shall be awared of the need of regular maintenance of terraces (not only if there is a damaged bund) to have the desired outcome.

- This study doesn’t incorporate sufficient number of soil samples. Besides, in the field survey, the researcher faced problems while trying to take soil samples from non-terraced farm plots. Thus, further studies need to be conducted to correct the cited problems of this study as well as covering a larger area.
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APPENDIX I

QUESTIONNAIRE FOR HOUSEHOLD HEADS

This questionnaire is prepared for two reasons:
- to explore farmers’ opinions about the problems and benefits of terraces.
- to prepare thesis for the partial fulfillment of the requirements for Master of Arts in Geography & Environmental Studies.

Hence, taking the above objectives into consideration, you are kindly asked to provide the appropriate answer for the following questions.

Date of Interview _____________________

I. INFORMATION ON SOCIO-ECONOMIC CHARACTERISTICS OF HOUSEHOLD HEADS

1. Name of household head: ______________________________________________

2. Age: __________________

3. Sex
   A. Male                           B. Female

4. Marital status
   A. Married                      C. Widowed
   B. Divorced                     D. Single

5. Level of education
   A. Can read and write           C. 1-8th grade          E. Above 12th grade
   B. Can’t read and write         D. 9-12th grade

6. Number of household size: ________________

7. Number of Children: ________________

8. Number of dependants/other relatives: ________________

9. What is the total size of your farm in hectare including homestead?
   ____________________________________________________________________
## II. INFORMATION ON TERRACE

10. How many farm plots do you have? 

____________________________________________________________________

11. Information on each farm plot

<table>
<thead>
<tr>
<th>No. of plots</th>
<th>Size of each plot</th>
<th>Slope position</th>
<th>Terraced</th>
<th>Distance between Plots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Upslope</td>
<td>Middle</td>
<td>Downslope</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
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</table>

12. What conservation measures do you employ for your farm plot(s) which are not terraced?

A. Contour cultivation  
B. Fallowing  
C. Drainage ditches and waterways  
D. Use of manure  
E. Crop rotation  
F. Mixed cropping  
G. Other (please specify) ____  

______________________________
13. If you do have terraced farm plots outside the Minchet catchment, did you incorporate it to your plot(s) by your own interest?
   A. Yes                                 B. No

14. If your answer for question no. 13 is ‘No’, who persuaded/obliged you to incorporate it?
   ____________________________________________________________________

15. When was your farm plot conserved with terrace?
   ____________________________________________________________________

16. How was your farm plot conserved with terrace?
   A. Through campaign that was held from Feb. – April 1986
   B. Using own family labour source
   C. Other (please specify) _____________________________________________

17. If your answer for question no. 16 is choice ‘B’, who told you the information regarding the way of construction?
   A. Own experience                            C. Neighbor(s)
   B. DA (or any SWC expert)             D. Other (please specify)____________
   ____________________________________________________________________

18. How was the soil erosion on your farm plot(s) before the introduction of terrace?
   A. No soil erosion                             C. Moderate soil erosion
   B. Slight soil erosion                         D. Severe soil erosion

19. Have you observed soil erosion problems under your farm plot now treated with terraces?
   A. Yes                                                 B. No

20. If your answer for question no 19 is ‘Yes’, how is the soil erosion?
   A. Slight erosion                            C. Severe soil erosion
   B. Moderate erosion

21. On which part of the terraced farm plot(s) the soil erosion process is severe?
   A. At the upper section of the terrace
C. At the lower section of
B. At the middle of the cultivated field

22. What do you think about the major causes of erosion on your farm plot(s)? (You can provide more than one answer)
A. Steepness of the field
B. Intensive cultivation
C. Heavy rainfall
D. Deforestation
E. Overgrazing
F. Up and down ploughing
G. Roads or footpaths that cross plots
H. Not practicing crop rotation
I. All
J. Other (please specify) ________________

23. What are the impacts of erosion on your farm plot?
A. Loss of soil fertility
B. Loss of soil
C. Reduction in yield
D. All
E. Other (please specify) ________________

24. What has been done by yourself to minimize soil erosion problem under the farm plot conserved with terraces?
____________________________________________________________________
____________________________________________________________________

25. Do you have both terraced farm plot(s) in the Minchet catchment and non-terraced farm plot(s) outside the catchment?
A. Yes
B. No

26. If your answer for question no. 25 is ‘Yes’, have you noticed any difference between them in terms of:
A) their fertility
B) their susceptibility to erosion
C) their yield

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
27. If your answer for question no. 25 is ‘Yes’, based on your experience of both terraced and non-terraced farm plots, can you say it is possible to control erosion using terraces?
   A. Yes                                          B. No

28. Do you have the experience of maintaining terraces?
   A. Yes                                           B. No

29. If your answer for question no. 28 is ‘Yes’, how many times did you maintain it until now?

_____________________________________________________________________

30. If your answer for question no. 28 is ‘Yes’, how did you maintain it?
   A. Stabilizing by leaving the riser slope with grass cover
   B. Redeveloping the terrace bunds
   C. Digging drainage ditches across plots
   D. Planting bushes or trees along the bunds
   E. Stabilizing the damaged terrace bunds with stone and soil
   F. Other (please specify) ____________________________________________________________________

31. If your answer for question no. 28 is ‘Yes’, what is the source(s) of labour for maintenance?
   A. Father             C. Hired labour        E. Family
   B. Mother           D. Children              F. Other (please specify) ______
                        ____________________________

32. If your answer for question no. 28 is ‘No’, why did you not maintain it?
   A. Because of non-existence of erosion
   B. Because of only slight erosion
   C. Because of the difficulty of up and down ploughing
   D. Because of loss of cropland
   E. Because of the unavailability of labour
   F. Because of lack of knowledge
   G. All
   H. Other (please specify) ____________________________________________
33. If you are in need of help for the maintenance of terrace, what kind of help do you need?
   A. Education              C. Farming instruments like shovel and pickaxe
   B. Labour                   D. Other (please specify)_______________________

34. Do you want to continue by incorporating terrace on your farm plot(s)?
   A. Yes                                   B. No

35. How is the agricultural productivity of your farm plot(s) after the introduction of terraces?
   A. Reducing B. Increasing C. Remain the same

36. Did you destroy one of the lines or more of the terrace?
   A. Yes B. No

37. If your answer for question no 36 is ‘Yes’, why did you destroy it?
   A. Because of the reduction of yield
   B. Because of the narrowing of cropland
   C. Because it makes farming difficult
   D. Because it requires higher labour input for maintenance
   E. All
   F. Other (please specify)_______________________

38. Have you ever vertically dug the terrace riser?
   A. Yes B. No

39. If your answer for question no. 38 is ‘Yes’, why you did so?
   ___________________________________________________________________

40. If your answer for question no. 38 is ‘No’, what do you do instead?
   ___________________________________________________________________

41. Generally, how do you rate terraces as compared to other SWC methods?
   A. Bad C. Good E. Excellent
   B. Fair D. Very good
42. Do you consider yourself as a beneficiary of the terrace?
A. Yes                             B. No

43. If your answer for question no. 42 is ‘Yes’, what are the benefits that you have gained by incorporating it?
A. Having less rills on the cropland plot and hence less erosion of seedlings
B. Increase in soil fertility by conserving soil
C. Increase in soil moisture by conserving water
D. Increase in yield
E. All
F. Other (please specify) ________________________________

44. What problems do you notice about terraces?
A. The terrace is too narrow making farming difficult
B. The vertical waterway which develops into gullies
C. Overflow of runoff during heavy storms
D. Require larger labour and financial investment
E. All
F. Other (please specify) ________________________________

45. What do you say about the solutions to solve or at least minimize these problems of terraces?
__________________________________________________________
__________________________________________________________
Appendix II

Rating of Total Nitrogen (%) and Organic Carbon (%) Contents (Landon, 1991)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Very high</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
<th>Very low</th>
</tr>
</thead>
<tbody>
<tr>
<td>TN (Kjeldhal method)</td>
<td>&gt; 1</td>
<td>0.5 - 1</td>
<td>0.2 - 0.5</td>
<td>0.1 - 0.2</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>OC(Walkley-Black method)</td>
<td>&gt; 20</td>
<td>10 - 20</td>
<td>4 - 10</td>
<td>2 - 4</td>
<td>&lt; 2</td>
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</tbody>
</table>

Rating of Available Phosphorus (PPM) and Available Potassium (Meq/100g) (Landon, 1991)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ava. P (Bray Dilute HCl/NH4F method)</td>
<td>&gt; 50</td>
<td>10 - 15</td>
<td>&lt; 15</td>
<td>High values difficult to interpret</td>
</tr>
<tr>
<td>Ava. K (Ammonium Acetate Extraction)</td>
<td>0.8-0.4</td>
<td>0.4-0.2</td>
<td>0.2-0.03</td>
<td>Based on Malawi soils</td>
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</tbody>
</table>

Rating of CEC (Meq/100g) Results for Topsoils (Landon, 1994)

<table>
<thead>
<tr>
<th>CEC</th>
<th>Rating</th>
</tr>
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<tbody>
<tr>
<td>&gt; 40</td>
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</tr>
<tr>
<td>25 -40</td>
<td>High</td>
</tr>
<tr>
<td>15 - 25</td>
<td>Medium</td>
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<tr>
<td>5 - 15</td>
<td>Low</td>
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<tr>
<td>&lt; 5</td>
<td>Very low</td>
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</table>
Rating of Acidity of Soils (Olaitan et al, 1984)

<table>
<thead>
<tr>
<th>PH</th>
<th>Rating</th>
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<tbody>
<tr>
<td>4.0</td>
<td>Very strongly acidic</td>
</tr>
<tr>
<td>4.5</td>
<td>Very acidic</td>
</tr>
<tr>
<td>5.0</td>
<td>Acidic</td>
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<tr>
<td>5.5</td>
<td>Moderately acidic</td>
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<tr>
<td>6.0</td>
<td>Slightly acidic</td>
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<tr>
<td>6.5</td>
<td>Very slightly acidic</td>
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</table>
Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other university and that all sources of materials used for the thesis have been duly acknowledged.

Declared by:

Name: Alemayehu Assefa

Signature: ————————————

Date: ————————————