

***CLIENT***



***OROMIA IRRIGATION DEVELOPMENT AUTHORITY***

**Feasibility Study for Fir Kebso SSI Project in East Hararghe Zone Malka Balo Woreda**  
***DRAFT FEASIBILITY REPORT OF WATERSHED MANAGEMENT***

**CONSULTANT**



**OROMIA WATER WORK DESIGN &  
SUPERVISION ENTERPRISE (OWWDSE)**

**April, 2019**

**FINFINNE**

## TABLE OF CONTENTS

<b>1. INTRODUCTION.....</b>	<b>1</b>
1.1. BACKGROUND TO THE WATERSHED STUDY.....	1
1.2. PRINCIPLES OF INTEGRATED WATERSHED MANAGEMENT.....	2
<b>2. OBJECTIVES AND SCOPE OF THE STUDY .....</b>	<b>4</b>
2.1. GENERAL OBJECTIVES .....	4
2.2. SPECIFIC OBJECTIVES.....	4
2.3. SCOPE OF THE STUDY.....	4
<b>3. METHOD OF THE STUDY .....</b>	<b>7</b>
3.1. DATA COLLECTION METHODS.....	7
3.2. DATA ANALYSIS .....	7
3.3. DEVELOPMENT PLAN GENERATION .....	8
3.4. DESIGN OF IMPLEMENTATION STRATEGIES.....	8
<b>4. REVIEW OF STRATEGIES, POLICIES AND PREVIOUS STUDIES.....</b>	<b>9</b>
4.1. GENERAL.....	9
4.2. PREVIOUS STUDIES .....	9
4.2.1. <i>The Ethiopian Highland Reclamation Studies.....</i>	<i>9</i>
4.3. STRATEGIES, POLICIES AND CONSTITUTION.....	10
4.3.1. <i>Environmental Policy (1997b).....</i>	<i>10</i>
4.3.2. <i>Rural Land Administration and Land Use Proclamation (2005).....</i>	<i>10</i>
4.3.3. <i>The National Conservation Strategy .....</i>	<i>12</i>
4.3.4. <i>Food Security Strategy .....</i>	<i>13</i>
4.3.5. <i>The Ethiopian Constitution.....</i>	<i>13</i>
4.4. WATERSHED DEVELOPMENT IN ETHIOPIA AND LESSONS LEARNED.....	14
<b>5. DESCRIPTION OF THE WATERSHED.....</b>	<b>16</b>
5.1. BIOPHYSICAL FEATURES OF THE WATERSHED AREA .....	16
5.1.1. <i>Location.....</i>	<i>16</i>

5.1.2. Climate.....	18
5.1.3. Topography.....	18
5.1.4. Watershed Shape .....	20
5.1.5. <b>Watershed Length</b> .....	21
5.1.6. <b>Land use and cover</b> .....	22
5.1.7. Soils of the study area.....	23
<b>6. EXISTING SOCIO-ECONOMIC CONDITION, AGRICULTURAL AND SWC ACTIVITIES.....</b>	<b>25</b>
6.1. SOCIOECONOMICS.....	25
6.1.1. Farming System and Crop Production Practices.....	25
6.1.2. Source of Energy .....	25
6.1.3. Land Holding or tenure .....	25
6.1.4. Cropping pattern .....	26
6.1.5. Major Livelihood Options .....	26
6.1.6. Existing Soil and Water Conservation Activities.....	26
<b>7. EROSION HAZARD ASSESSMENT .....</b>	<b>29</b>
7.1. GENERAL.....	29
7.2. CAUSE OF SOIL EROSION .....	29
7.3. EFFECT OF SOIL EROSION .....	30
7.4. ESTIMATION OF SOIL LOSS .....	31
7.4.1. Rainfall Erosivity (R) Factor.....	32
7.4.2. Soil Erodibility (K) Factor: .....	32
7.4.3. Slope Gradient and Slope Length (LS) Factors.....	33
7.4.4. Crop management (C-values) factor .....	33
7.4.5. Conservation practices (P-Values).....	34
<b>8. HYDROLOGICAL AND SEDIMENT YIELD ANALYSIS .....</b>	<b>38</b>

8.1. FLOOD ESTIMATION .....38

8.2. DATA AVAILABILITY AND PROCEDURES .....38

8.3. SEDIMENT DELIVERY RATIO COMPUTATION.....41

**9. WATERSHED DEGRADATION AND MAJOR PROBLEMS OF THE WATERSHED44**

9.1. WATERSHED DEGRADATION .....44

9.2. MAJOR WATERSHED PROBLEMS .....45

    9.2.1. *Productivity and Production Decrease* .....45

    9.2.2. *Deforestation* .....46

    9.2.3. *Soil Erosion* .....46

    9.2.4. *Capacity Gaps with Respect to effective Watershed Management*.....47

**10. LAND CAPABILITY CLASSIFICATION ..... 48**

10.1. GENERAL .....48

10.2. CRITERIA FOR LAND CAPABILITY CLASSIFICATION .....48

10.3. HOW TO USE THE LAND CAPABILITY CLASSIFICATION TABLE AND DETERMINING THE SCRC .....50

10.4. SOIL AND WATER CONSERVATION REQUIREMENT CLASSES (SWCRCS) ...52

**11. WATERSHED DEVELOPMENT OPPORTUNITIES..... 56**

11.1. GENERAL .....56

11.1. OPPORTUNITIES .....56

**12. WATERSHED DEVELOPMENT INTERVENTIONS ..... 58**

12.1. MAIN COMPONENTS .....58

12.2. SOIL AND WATER CONSERVATION .....58

    12.2.1. *Physical Soil and Water Conservation Measures* .....58

    12.2.2. *Biological Soil and Water Conservation Measures* .....58

    12.2.3. *Agro-Forestry Development Interventions*.....59

    12.2.4. *Gully Control and Rehabilitation*.....59

    12.2.5. *River bank Protection*.....59

12.3. PROMOTE FRUIT PRODUCTION.....60

12.4. WATER SUPPLY AND SANITATION .....60

12.5. ACCESS FOR CREDIT SERVICES.....60

12.6. HOMESTEAD FARMING .....60

12.7. VEGETABLE PRODUCTION.....61

12.8. DIVERSIFYING ANIMAL PRODUCTION AND IMPROVE PRODUCTIVITY .....61

12.9. INTRODUCE FUEL SAVING STOVE FOR ENERGY SOURCE .....62

**13. PROPOSED WATERSHED DEVELOPMENT PLAN ..... 63**

13.1. HOT SPOT AREAS IDENTIFICATION .....63

13.2. PROPOSED WATERSHED DEVELOPMENT PLAN AND OPTIONS .....63

13.3. PROPOSED WATERSHED DEVELOPMENT MAP.....66

**14. IMPLEMENTATION PLAN, COST ESTIMATE AND BENEFITS ..... 68**

14.1. IMPLEMENTATION PLANS & SCHEDULE.....68

14.2. INPUTS AND COST ESTIMATES FOR THE WATERSHED DEVELOPMENT .....70

14.3. BENEFITS .....73

14.4. IMPLEMENTATION STRATEGIES .....74

**15. MONITORING AND EVALUATION ..... 77**

**16. CONCLUSION AND RECOMMENDATION ..... 78**

**REFERENCES..... 80**

**APPENDICES ..... 82**

## LIST OF TABLES

Table 5-1: Area coverage of watersheds and Micro-watersheds .....	16
Table 5-2: Description of landforms and slope classes of the study area .....	19
Table 5-3: Study watersheds physical characteristics.....	21
Table 5-4: Land Use and Land Cover Of the Watershed.....	22
Table5- 5: Area Distribution of the soil types within in the watershed .....	23
Table 6-1: Biological soil and water conservation intervention in Malka Balo wereda.....	27
Table 7-1: Combined Slope Length and Gradient Factor .....	33
Table 7-2: C Factor Values Used to Predict Erosion Hazard .....	34
Table 7-3: Management Factor Values.....	35
Table 7-4: Estimated annual soil Loss of the watershed.....	36
Table 8-1: Maximum storm value (mm) in 24 hrs for T year’s returns period .....	41
Table 8-2: Parameters for each watershed upstream of the proposed site .....	41
Table 8-3 : Peak flood estimated for Free Kebso Spring by SCS method.....	41
Table 8-4: Sediment deliver ratio and estimated annual sediment yield at each drainage outlet system .....	42
Table 10-1: Classes of the Limiting Factors, Range Of Values, And Coding For Different Factors.....	49
Table 10-2: The Escobedo Land capability classification table re .....	52
Table 10-3: Soil conservation requirement class and suitable land use.....	52
Table 10-4: Land Capability Subclass computation results by micro-watershed.....	53
Table 13-1: Proposed Development plan and Options of Conservation Practices by land capability sub-class .....	64
Table 13-2: Legend for Fir Kebso SSIP Watershed Development Map .....	66
Table 14-1: Development Interventions Implementation plans & Schedule.....	68
Table 14-2: Cost Estimate for development activities .....	70

Table 14-3: Materials requirements and cost estimate .....72

**LIST OF FIGURES**

Figure 5- 1: Location & Drainage map of the watershed .....17

Figure 5- 2: Slope Map of Fir Kabso SSIP Watershed .....20

Figure5- 3: Land use and cover of Fir Kabso SSIP Watershed .....22

Figure 5- 4: Soil Map of Fir Kabso SSIP Watershed.....24

Figure 6-1: Soil conservation structures existing on farmland .....27

Figure 7-1: Map of the Annual Soil loss of the Watershed .....37

Figure 10-1: Map of land capability sub-class of the watershed .....55

Figure 13-1: Fir Kebso SSIP Watershed Development Map.....67

Figure 15-1: The need for monitoring and evaluation .....77

# 1. INTRODUCTION

## 1.1. BACKGROUND TO THE WATERSHED STUDY

The problem of land degradation and decline of food production potential in poor rural economies with fast growing populations has received increasing attention in recent years. Among several causes for this, improper and unwise utilization of watershed resources without any conservation work has the leading role in this respect.

In Ethiopia, planning watershed development traced back in the 1980s constituting 30-40 thousand hectares of large watershed as planning unit. The purpose was to implement natural resource conservation development programs. However, the large-scale ones remained mostly unsatisfactory due to lack of participation, limited sense of responsibility over asset created, and unmanageable planning units. In addition, expanding human population and their increasing demands for natural resources led to exploitation and degradation of land and water resources. Expanding demands for cultivation and other off farm activities has intensified watershed degradation.

Currently the idea of sustainable development using an integrated watershed development approach has received recognition by the Government of Ethiopia and development partners. Both Federal and regional governments have consistently shown a strong commitment to address the issue of land degradation by implementing various water and land management activities for poverty alleviation and environmental conservation.

Integrated watershed development is the rational use of land for optimum production with minimum hazard to natural resources. It essentially relates to soil quality maintenance and improving soil fertility, conserving water for farm use, reduce sediment inflow to downstream areas and irrigation schemes, water management and increase land productivity. This will also ensures equity of benefits from development interventions among upstream and downstream community.

In view of this, Oromia Water Works Design and Supervision Enterprise (OWWDSE) in the Fir Kebso watershed conducted a watershed management study as part of Fir Kebso Irrigation Study and Detail Design Project.

This report, therefore, presents Introduction, review of past studies, relevant polices and proclamations, methodology of the study, description of biophysical and socio-economic

conditions, identification of potentials and proposed multi -disciplinary and integrated watershed management interventions. Moreover, the report outlines estimated cost and implementation strategies

## **1.2. PRINCIPLES OF INTEGRATED WATERSHED MANAGEMENT**

A watershed is made up of the natural resources in a basin, especially water, soil, and vegetative factors. Watershed management is the integration of technologies within the natural boundaries of a drainage area for optimum development of land, water, and plant resources to meet the basic needs of people and animals in a sustainable manner. The approach integrates various aspects of forestry, agriculture, hydrology, ecology, soils, climatology and other sciences. However, it is more than natural science methods and tools. Rather, watershed management is a continuous and participatory process that involves people and aims to improve their livelihoods. The main principles of watershed management are the following:

- Sustainable management of natural resources,
- soil conservation based farming system,
- Watershed logic : adoption of ridge to valley approach,
- due emphasis on production enhancement for land users,
- livelihood support for land users,
- Income diversification,
- Flexibility,
- integration and synergic effects of multi disciplines,
- manageable size,
- genuine community participation,
- building upon indigenous innovations and experiences,
- equity for resource poor families,
- Gender equity.

Linkages between watershed and micro-watersheds and its impact on the downstream are also the other guiding principles of watershed management. Moreover, WSM necessitates

cooperation and integration of all including land users, development actors and institutions working in the watershed area, directly and /or through their grass root institutions.

## **2. OBJECTIVES AND SCOPE OF THE STUDY**

### **2.1. GENERAL OBJECTIVES**

The general objective of the study is to identify biophysical and socio-economic potentials and constraints in the watershed, upstream of the proposed diversion site and put forward recommendations for future conservation and rehabilitation of natural resources to control soil erosion and land degradation in the watershed and thereby to minimize sediment inflow to the proposed schemes.

### **2.2. SPECIFIC OBJECTIVES**

The specific objectives of the study were to:

- Assesses biophysical and socio-economic features of the watershed area draining in to the proposed scheme site;
- Asses and analyse status of soil erosion and land degradation of the watershed and its micro-watershed;
- Evaluate past and present experiences on soil and water conservation measures adopted in the country;
- Assess institutional capacity, and policy issues related to natural resources management;
- Carryout land capability classification to identify SWC requirement classes to decide on required soil and water conservation measures;
- Undertake problem analysis and propose appropriate watershed management measures and strategies along with responsible institution and implementation cost estimation.

### **2.3. SCOPE OF THE STUDY**

The scope of a watershed management study can be broaden beyond the Natural Resources management (NRM) interventions depending on the biophysical and socio-economic potentials and constraints of the watershed management. As stipulated in the TOR, this study has given high emphasis to conservation, rehabilitation and development of natural resources that will

mainly contribute to reduce soil erosion and land degradation problems in the watershed and thereby to reduce sedimentation on proposed infrastructures.

Generally, the study encompasses assessing and analyzing of biophysical and socio-economic situation of the watershed and propose appropriate watershed management interventions and strategies along with the responsible institution arrangements.

Therefore, the scope of this watershed management study includes the following:

- Review the available data, policies and proclamations related to natural resources management
- Delineate the watershed boundary and interpret slope and drainage characteristics,
- Make site investigation in the Fir Kebso watershed and make consultation at community and woreda level concerned government institutions.
- Make assessment of the biophysical resources (investigation of land, water, biological resources),
- Make evaluation of implemented interventions in the watershed (physical soil and water conservation activities, livelihoods activities, etc),
- Collect and interpret land use/land cover of the watershed area from recently land-sat digital image data using Image processing software and GPS records of the control points ,
- Identify the agro-ecology and soil characteristics of the watershed and interpret in terms of soil erosion , potentials and constraints for agriculture development
- Identify development interventions which would be implemented in the future interventions,
- Undertake land capability classification to identify required soil and water conservation practice and techniques,
- Analyse identified major problems of the watershed area and recommend possible watershed management interventions ,
- Develop action plan and estimate financial and material resources requirement to implement the planned IWSM interventions

Consequently, bearing these points in mind and understanding the project area, the watershed study, data analysis, interpretation and a systematic evaluation and mapping showing the levels of different degradation occurring in each micro-watershed are made which will be a benchmark and quite fundamental to make use of the data for development activity.

Accordingly, the study report outlines the description of biophysical, soil erosion and land degradation and socioeconomic features of the watershed. This is followed by a brief discussion of the main proposed watershed management measures, which can be used, and suggestions on which ones are most appropriate for different land uses types.

This study considers existing strategies and any strategy proposals should be treated not as blue prints but as guidelines, which will be developed or modified in the light of field experience and during detailed community based watershed development planning process.

The study also indicated financial and materials requirement as indicative based on the scale of proposed interventions. They are inevitably preliminary and tentative but it is hoped that the exercise will help to clarify some of the issues involved in watershed management

### 3. METHOD OF THE STUDY

#### 3.1. DATA COLLECTION METHODS

The methods for the preparation of the Fir Kebso watershed development plan were standard procedures aimed at enabling to look at different levels in the system hierarchy in relation to watershed characterization, emphasizing on diversity, potentials and constraints of the existing land management practices existing in the study area. Thus, every activity was carefully conducted to examine potential, constraint and all related factors.

- Data collection starts at the watershed boundary delineation, followed by interpretation of slope and drainage characteristics, which were done employing a 1:50,000 scale topographic map and using Geographic information system (GIS).
- Secondary data were collected from previous studies and Malka Balo Agriculture & natural resource Office;
- Field observation was made to collect biophysical data while conducting transect walk. Biophysical data are collected for each land unit. At the same time, socio-economic data were collected from the community and watershed committee.
- The planning and data collection methods engaged Focus Group Discussions (FGD) with the different stakeholders, Key Informant Interviews (KII) and field observation in addition to secondary documents from different offices.
- A preliminary watershed development plan was developed by the study team and major findings along with the development plan were discussed with the objective of validating the findings. Discussion made with experts from Malka Balo woreda, in a meeting held at the Office of Agriculture with the attendance of the concerned experts.

#### 3.2. DATA ANALYSIS

The study figured out major socio-economic findings and biophysical observations and defined major watershed characteristics. The major findings from the socio-economic condition such as major problems and livelihood options were collated along with the major findings of the biophysical data including the land capability classes and specific current land uses. Major problems were identified and interpreted along with their root causes, and allied with the watershed management interventions and demands.

Physical watershed characterization was made employing watershed morphology parameters and assessment of soil erosion made employing the Universal Soil Loss Equation (USLE) as adapted to the Ethiopian condition. Land capability classification was done employing the USDA land capability classification guideline as adapted to the Ethiopian condition (MoA, 1990). The physical limiting factors in the Soil Conservation Requirements were matched with the watershed problems extracted from the biophysical and socio-economic analysis.

### **3.3. DEVELOPMENT PLAN GENERATION**

As a final product, the watershed development options were defined by combining the result of the socio-economic and biophysical information. The development interventions were designed for each specific land unit based on proposed land use options. GIS was used to interpret, analyze, and visualize the land features (soil, land cover, slope and land capability classes) and to produce the various thematic maps.

### **3.4. DESIGN OF IMPLEMENTATION STRATEGIES**

The implementation of the development intervention is the final goal of the development of watershed development plans. Therefore, the team realizes the critical need of defining clear implementation strategy. The strategies are defined based on the current watershed development interventions, experience of the community, employing the study team exposures.

## 4. REVIEW OF STRATEGIES, POLICIES AND PREVIOUS STUDIES

### 4.1. GENERAL

Watersheds degradation in many developing countries threatens the livelihood of millions of people and constrains the ability of countries to develop a healthy agricultural and natural resource base. Apart from decline of land productivity, soil erosion in Ethiopia is also causing sedimentation of watercourses, lakes, and reservoirs and adversely affecting downstream flood plains. Sedimentation of reservoir is frequent in Ethiopia where many water harvesting structures and reservoirs were silted up. Siltation of water reservoir is the most challenging problem in Ethiopia (Admasu, 2005). That is, soil erosion by water is the most pressing environmental problem in Ethiopia, particularly in the highlands where the topography is highly rugged, population pressure is high, steep lands are cultivated and rainfall is erosive (Bewket *et al.*, 2009).

### 4.2. PREVIOUS STUDIES

#### 4.2.1. *The Ethiopian Highland Reclamation Studies*

Extensive studies were conducted on Ethiopian highlands by the Ethiopian Highlands Reclamation Study, the output of these studies being a series of working papers, data sets and maps (EHRS, 1986). These reports provide information on the land degradation situation, generalized physical erosion hazard index along with the methodology followed, assessment of soil and water conservation activities and recommendations on focused strategies for the future.

Barber (Barber, 1984) and Wright (Wright, 1984) are the most prominent reports from the project which are relevant to the current study. Studies were carried out with the objective of assessing the nature, causes and relative importance of soil degradation processes in the Ethiopian Highlands. Moreover, they provided data on projected changes in soil fertility due to continued soil degradation, and assessment of the hazards of the dominant soil degradation processes in terms of their impacts on soil fertility with specific emphasis to erosion by water.

The important aspect of these studies lies in the methodology followed to determine soil degradation levels and erosion hazards. Due to the variations in conditions across Ethiopian Highlands, EHRS divided the highland area into three zones of crop potential and farming systems, each with three sub-zones based on altitude, in order to solve the problems faced, to

fulfil the above mentioned objectives, and to prepare a development strategy for the whole highland area. These three zones are the Low Potential Cereal Zone (LPCZ), the High Potential Cereal Zone (HPCZ) and the High Potential Perennial Zone (HPPZ).

The entire highlands of the watershed fall within HPPZ for investigating the status of accelerated erosion and soil formation rates; soil depth was used as an important and single indicator. While assessing the situation of soil erosion, it was assumed that the sheet and rill erosion rates remain approximately constant over a 25 year period, with 1985 as the start year.

### **4.3. STRATEGIES, POLICIES AND CONSTITUTION**

Several policies, strategies and constitutions have been promulgated at federal level, referring to and supporting the need for development and conservation of natural resources. The national policy on natural resources and the environmental sector has the objective of promoting improved soil conservation practices that enhance and maintain land productivity for sustainable development of agriculture, and in general, biomass and biodiversity.

#### *4.3.1. Environmental Policy (1997b)*

Demands on natural resources often deplete those resources, and, especially when not managed well, disturb the local ecosystems causing general land degradation. During their extraction, local transportation, processing for value addition and export, additional environmental degradation, and in particular pollution, occurs to varying degrees. People, in their attempt to survive, are forced to disregard the long-term well-being of the environment and thus degrade it further. Environmental degradation and poverty are thus interactive leading to a spiral of environmental and human calamity. The Environmental Policy of Ethiopia, which was extracted from the Conservation Strategy of Ethiopia (CSE), was approved on April 2, 1997 by the Council of Ministers. The CSE and thus the Environmental Policy is the result of seven years of consultation, and data collection and analysis.

#### *4.3.2. Rural Land Administration and Land Use Proclamation (2005)*

In past years, there were no rules and regulations with respect to land use. Very steep slopes, which could lead to severe erosion/land degradation, have been cultivated for crops without any regard for soil conservation. Hence, it has become necessary to conserve and develop natural resources through the development and implementation of sustainable rural land use planning,

based on the different agro-ecological zones of the country. To fit in with this above objective, Proclamation no. 456/2005 had been promulgated by the federal government. This gives the right to hold and use rural land, allows land registration and the issue of holding certificates, the transfer of rural land rights, and defines the obligations of rural land users. Furthermore, the proclamation takes into account land use planning and proper use of sloping, gully associated lands and wetlands. Here, part of the proclamation that restricts rural land use in the context of “the land use planning and proper use of sloppy, gully and wetlands”, which is relevant to watershed management is summarized below.

A guiding land use master plan which takes into account soil type, land form, climate, plant cover and the socioeconomic, and which is based on a watershed approach, shall be developed by the competent authority and implemented.

- Equitable water use system between upper and lower watershed communities shall be affected
- In any type of rural land where soil water conservation works have been undertaken, a system of free grazing shall be prohibited and a system of cut and carry feeding shall be introduced step by step
- The management of rural lands, where the slope is less than 30%, shall follow the strategy of soil conservation and water harvesting
- Development of annual crops on rural lands that have slopes between 31 and 60 % shall be allowed only by benching terraces
- Rural lands, where the slope is more than 60%, shall not be used for farming and free grazing; they shall be used for development of trees, perennial plants and forage production
- Rural land of any slope which is highly degraded shall be closed from human and animal interference for a given period of time to let it recover, and shall be put to use when it has been ascertained that it has recovered; unless the degradation is caused by the negligence of the peasant farmers, semi pastoralist and pastorals, the users shall be given compensation or other alternatives during the interim period

- Rural lands that have gullies shall be rehabilitated by private and neighbouring landholders and, if appropriate, by work from the local community using biological and physical measures
- Rural lands that have gullies and are located on hilly areas shall be rehabilitated and developed communally and if appropriate, by private individuals
- The biodiversity in rural wetland shall be conserved and utilized as a necessity, in accordance with a suitable land use strategy.

The proclamation also gives provisions on the responsibility of the MoA and the regions. The proclamations of the regions (Proclamation no. 110/2007, Article 13 Sub-articles 1 to 17 for OROMIA) also provided legal restrictions to the use and management of rural land.

Development programs in the watershed should make use of these proclamations, which would offer strong support for the proper use and management of the natural resources in a sustainable manner.

#### *4.3.3. The National Conservation Strategy*

The National Conservation Strategy Ethiopia (NCSE, 1989) is an umbrella strategy which considers all sectors of human activity and enhances the capacity and effectiveness of existing and subsequent strategies. In this respect, the Conservation Strategy of Ethiopia (CSE) will play an important role in coordinating sectoral strategies.

The CSE recognizes the very low standard of living of the majority of Ethiopians and thus their minimal ability to invest in activities that do not yield quick returns. It is, therefore, realistic and works towards enhancing their ability and will to invest in conservation. The policy items were then separated and compiled in The Environmental Policy of Ethiopia. This Environmental Policy was formally approved by the government on 2 April 1997, and the understanding is that by doing so, the government has approved the entire CSE.

NCSE promotes to build up the use of indigenous soil management systems to-

- Develop and promote improved technologies
- Promote the use of farmyard, green manure, compost, biological nitrogen fixation, etc.
- Develop forestry on the farm, around the homestead, on eroding and/or eroded hillsides through a programme of farmers participatory research

- Determine specific agro-ecological zones and the relative effectiveness and economic advantages of physical and biological soil conservation systems, which are generally suitable for soil and water conservation
- Enhance and strengthen the holistic approach to research, extension and training of farmers, extension workers and researchers.

#### *4.3.4. Food Security Strategy*

The food security program outlined by the FDRE (2002) highlights the importance of sustainable use of the natural resources base. As described in the documents, this component aims at optimum use of land, protecting the natural resources base to enhance sustainable food security. It mainly focuses on

- Initiating soil conservation measures in areas where soil degradation is extremely high, improving forest management systems,
- Ensuring availability of fuel wood, construction materials and livestock feeds,
- Expanding and strengthening reforestation program on hilly sides and eroded steep slopes,
- Initiating soil survey and studies to increase the proper land use,
- Creating public awareness natural resources management and intensifying planting of multipurpose tree species (Fuel wood, Fodder, soil conservation etc)

#### *4.3.5. The Ethiopian Constitution*

This constitution was approved by the Constituent Assembly in December 1994, and among the any items it addressed, the following have relevancy to this study:

- Maintains land under the ownership of the Ethiopian people but protects the tenure security,
- Reinforces the devolution of power and local participation in planning, development and decision making,
- Ensures the appropriate management as well as protection of the well-being of the environment.

#### **4.4. WATERSHED DEVELOPMENT IN ETHIOPIA AND LESSONS LEARNED**

In Ethiopia, watershed based natural resource management in general and soil and water conservation in particular was commenced in the 1980's. However, the management was at unmanageable size of watershed and top- to- down planning approach which ignored the land users' participation. This had resulted to low sense of responsibility among the land users to sustain the implemented SWC activities. Moreover, it was strictly physical SWC measures like terrace on farmlands, hillside terraces for plantation, cutoff drains, waterways and check dams. Generally, there was no integration of physical and biological conservation measures in the past. Furthermore, community and government plantations had also carried out in extensive part of the country both for environmental rehabilitation and production of wood resources for various purposes.

The lessons learned from this experience encouraged MoA and support agencies like FAO, GiZ and WFP to initiate pilot watershed planning approaches on a bottom-up basis, using smaller units and following community-based approaches. A number of participatory planning tools and methodologies were developed and had tried out in Ethiopia. Most of these approaches emanated from combination of planning tools inspired by various methodologies and adaptation at the local level. The common ones were Minimum Planning, Participatory Rural Appraisal (PRA), Participatory Land Use Planning, Participatory Watershed Planning, and Local Level Participatory Planning Approach (LLPPA). Minimum planning at the initial stage involved shifting from larger watersheds to smaller watersheds or sub-watersheds.

The LLPPA developed within Managing Environmental Rehabilitation in Transition to Sustainable Livelihoods (MERET) project has gained national acceptance and ownership. It was a practical approach focusing mostly on integrated natural resource management interventions, productivity intensification measures, and small-scale community infrastructure development such as water, ponds and feeder roads. The LLPPA is community based sub-watershed development approach originated from the minimum planning. The LLPP was an ideal approach for land management and environment rehabilitation, in spite of it created dependency syndrome as it was linked with FFW program in the implementation of farm levels measures. This totally eroded farmers' sense of responsibility in maintaining and upgrading implemented activities and resulted in poor sustainability of implemented activities.

Recently, from several of these approaches, a community-based participatory watershed development guideline has been extracted to provide guidance to Development Agents and Woreda experts on how to engage and consult with communities to prepare a workable, socially acceptable, economically and ecologically technically sound community-based watershed management plan. The approaches, procedures and the techniques built-in this guideline are well accepted by all development organizations and communities. However, it did not yet fully realize in many parts of the country due to lack of knowledge and skills among the local staffs working on the area and low attention by the responsible government institution.

## 5. DESCRIPTION OF THE WATERSHED

### 5.1. BIOPHYSICAL FEATURES OF THE WATERSHED AREA

#### 5.1.1. Location

The Fir Kebso watershed is located in Shebele River Basin. It falls within fir kebso kebele Malka Balo Wereda and East Hararghe Zone of the OROMIA( see figure 5-1 below). Geographically the study area lies between 739000 to 753000 E longitudes and 993000 to 999000 N latitudes and comprised a total study area of 1285 ha of land.

The spring emerges from upper land of fir kebso and other Kebeles feed by the catchment. The main objective of the study is to develop Irrigation land with surface irrigation methods. Thus, it has reservoir storage and water distribution structures as main components of the project. The command area is entirely located below the watershed. Therefore, this watershed management study was considered upstream of the proposed diversion site. The study focuses on two micro-watersheds with land area 491 ha and 794 ha. See Table 5-1 below.

**Table 5-1: Area coverage of watersheds and Micro-watersheds**

No	Name of micro-watershed	Area	
		Ha	%
1	Fir Kebso Lower	491	38
2	Fir Kebso Upper	794	62
<b>Total area</b>		<b>1285</b>	<b>100</b>

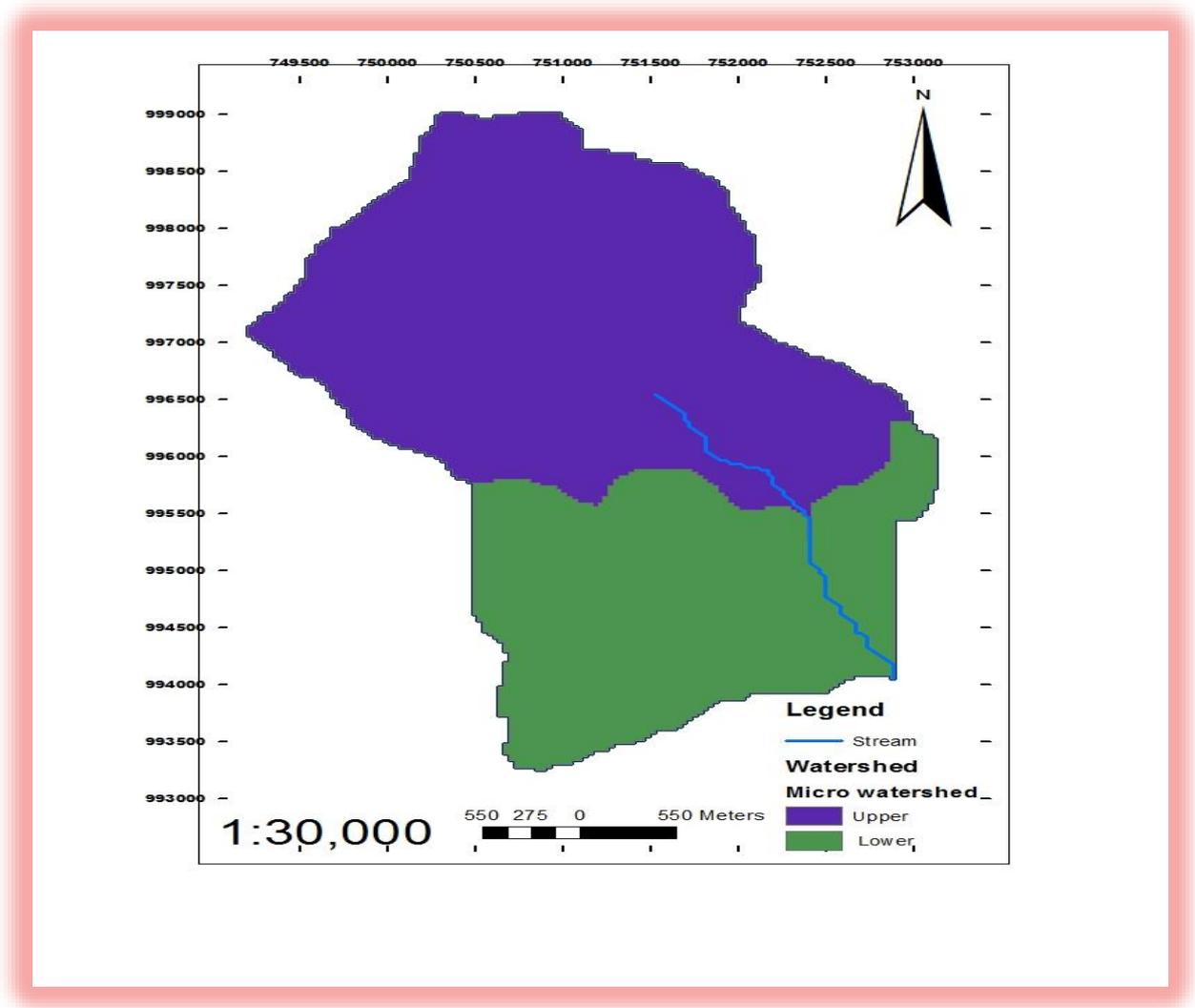


Figure 5- 1: Location & Drainage map of the watershed

### 5.1.2. Climate

Climate is the main agent determining the water balance in geo-hydrology and hydrology. Finally, climate largely determines the nature of the natural vegetation, and interactions of climate, relief, and soils are particularly important for land use. The main climatic information that is most important for watershed management is rainfall and temperature. Others like evapotranspiration, relative humidity, solar radiation, are subsidiary for planning watershed management.

The mean annually and monthly areal rainfall of the study area is analyzed using the Thiessen polygon with the grid rainfall data to describe the magnitude and seasonal variability of rainfall in the project area. The area characterized with long mono-modal rainfall regime with peak rainfall at August and average annual rainfall recorded was 1047.73 mm. The mean monthly maximum and minimum temperature is between 19.290c to 21.12<sup>0</sup>c and 9.290c to 11.60<sup>0</sup>c, respectively

### 5.1.3. Topography

The rate and volume of runoff, and sediment yield from the watersheds have much to do with slope and other parameters of the landscape. They also have negative impacts on the efficiency of soil and water conservation measures particularly that of physical SWC measures. Important terrain characteristics for studying soil erosion are sloping gradient, length, aspect and shape.

Slope analysis is an important step towards rationalization of land use in the watershed. It provides the basis for land capability classification, land use planning and soil conservation needs. The results show that the watershed has rugged terrain and steep slopes.

In general, some part of the land, which is also used for cultivation, has a slope of more than 8%, which creates accelerated erosion with the current poor vegetation cover and dominance of cultivated land use. Such types of slopes disfavors rainfall infiltration and tend to increase runoff in many cases. The ruggedness and steep slopes of the Watersheds has influenced not only the rainfall infiltration but also the development of soil and water conservation measures, which do require relatively deep excavation. The non-existent and at times limited undergrowth of grasses coupled with the nature of the topography is aggravating soil erosion. A slope map of Fir Kebso watershed is presented in Figure 5-2, and the results of slope analysis are shown in Table 5-2 below.

**Table 5-2: Description of landforms and slope classes of the study area**

No	Description of Landforms	Slope Classes (%)
1	Flat to gently slopping	0-8
2	Gently undulating to undulating	8-15
3	Rolling, strongly slopping	15-25
4	Moderately steep	25-35
5	Steep	>35

Slopes ranges more than 25% is not suitable for annual crop production, perhaps it could be good for forest, wildlife and watershed protection. However, in this study area, this slope classes are under cultivation in many places of the study area with limited or none SWC measures.

Naturally, the steeper the slope of a field, the more it is pushed down-hill, the faster the water runs and the greater will be the amount of soil loss from erosion by water. Flat land is very stable but soil losses increase rapidly with land sloping 2-5%. Land with a 10% slope has 8 times higher erosion, which makes it impossible to farm by ploughing, but perennial crops may be sustainable. At 15% slope, soil erosion has doubled again. However, slopes over 20% appear to be less affected, and the reasons for this could be that they are higher uphill, less prone to receive the water from a field higher up, and the run from hillcrest to valley floor is Fir Kebso.

Considering only the slope classes, more than 95% of the study area is susceptible to erosion by water coupled with improper land use practices and erodible nature of the soil characteristics prevails in the study area.

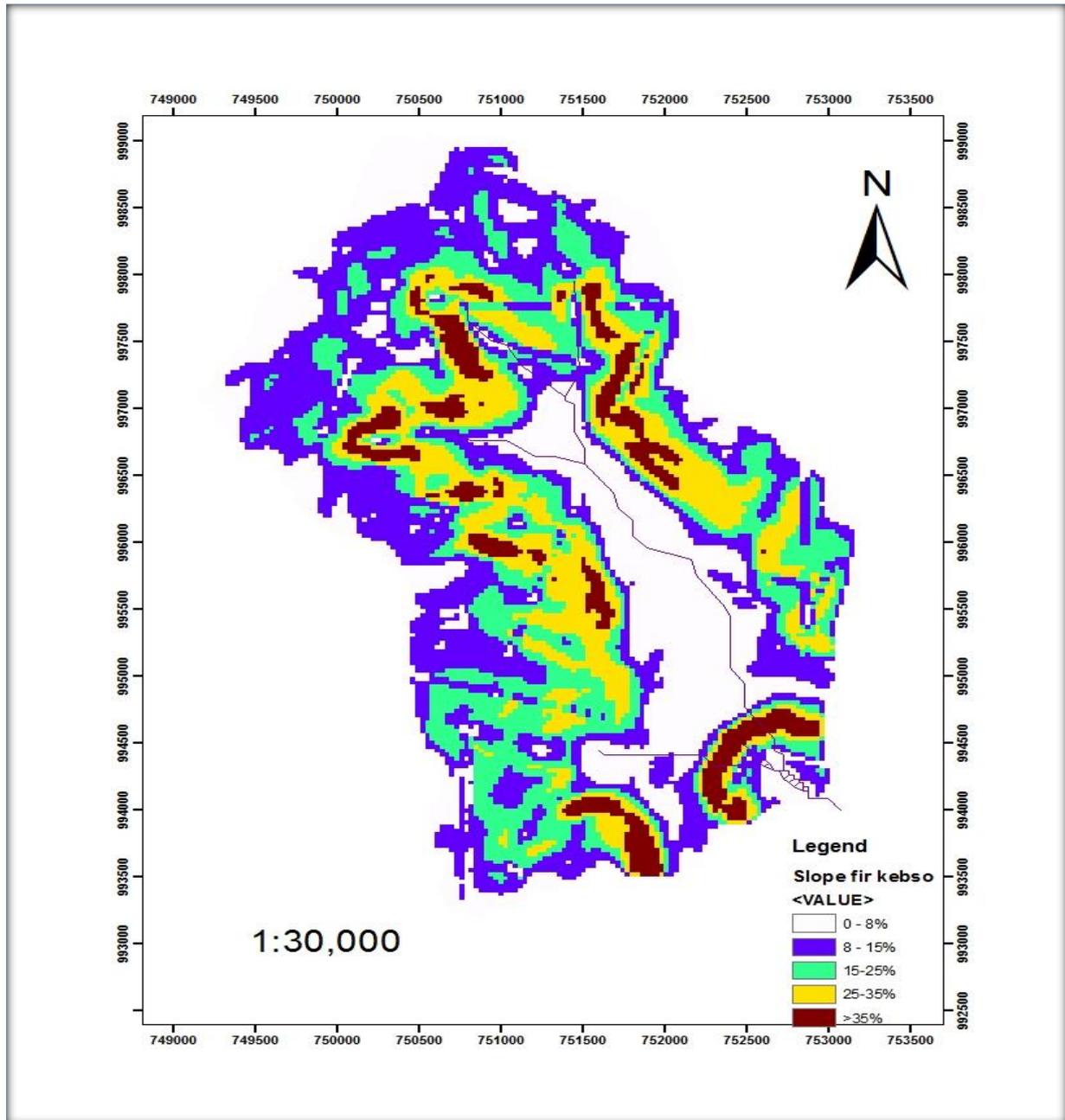


Figure 5- 2: Slope Map of Fir Kabso SSIP Watershed

5.1.4. Watershed Shape

Watershed shape has a significant contribution in runoff formation and subsequently to soil erosion and silt accumulation at the receptors. The impacts are determined based on watershed shape index, which would be calculated from axial length and average width of the watershed. For example, a long shape watershed generates, for the same rainfall, a lower outlet flow, as the concentration time is higher. A watershed having an oval-shape presents a lower concentration time, and it generates higher flow.

In this type of watershed shapes, tributaries are many in number and runoff from the system will reach quickly to one system and results in big water flow or flood crests, and carries large amount of sediment resulting in sedimentation and deposition problem in downstream lands and water bodies.

Different geomorphologic indices can be used for the analysis of a watershed if its shape is taken into consideration. The most frequently used index is the Gravelius's index KG, which is defined as the relation between the perimeter of the watershed and that of a circle having a surface equal to that of a watershed.

$$KG = \frac{P}{\sqrt{\pi A}} \approx 0.28 \frac{P}{A}$$

Where,

KG = Gravelius shape index

A= watershed Area (Km<sup>2</sup>)

P= Watershed perimeter (km)

**Table 5-3: Study watersheds physical characteristics**

No	Micro-watershed	Area (km <sup>2</sup> )	Perimeter (km)	KG Value
1	Fir Kabso Upper	7.9	16.2	0.57
2	Fir Kabso Lower	4.95	13.5	0.76

As can be indicated in the table 5-3, the shape of the drainage area of the micro- watershed Fir Kabso Lower is somewhat long fern shape with shape factor of 0.76, which indicates the time of concentration is higher that generates lower runoff at the outlet for a given rainfall. On the other hand, the micro-watershed Fir Kabso Upper as KG value of 0.57 and hence lower time of concentration that could be generated higher runoff at the outlet of the watershed system for the same amount of rainfall.

#### 5.1.5. Watershed Length

Watershed length refers to the length of the watershed from the remote part to the outlet, where it empties to a defined recipient. The axial length of the micro-watershed as related to its width become small, the time of concentration become low. The Fir Kabso time of concentration, more water/runoff will be formed at a time resulting in major erosion risk at the watershed. This would finally lead to a contribution of more silt to the reservoir.

5.1.6. Land use and cover

The land use/cover description includes the structural description of the natural vegetation as well as the cultivated lands. Land cover includes the different features covering the earth surface such as water, cultivated land, forest and other vegetation. Land use refers to the use that is made of the various land covers e.g. agriculture, grazing, timber production, recreation, fishing and the likes.

The extent of the area of land use and land cover mapping units in the watershed is highly dependent on the climatic, topography and edaphically factors. Population, remoteness and traditional factors attributed to the type of use and the natural vegetation as they are presently expressed in the watershed. As shown below in the table, out of the total 1285 ha, about 85 percent of the watershed area (1085 ha) is open bush land, 200ha (15 percent) is Moderately cultivated. The details are presented in Table 5-4 and Figure 5-3.

Table 5-4: Land Use and Land Cover Of the Watershed

NO.	Land use/cover	Area	
		ha	%
1	Moderately cultivated	200	15
2	Open bush land	1085	85
<b>Total area</b>		<b>1285</b>	<b>100</b>

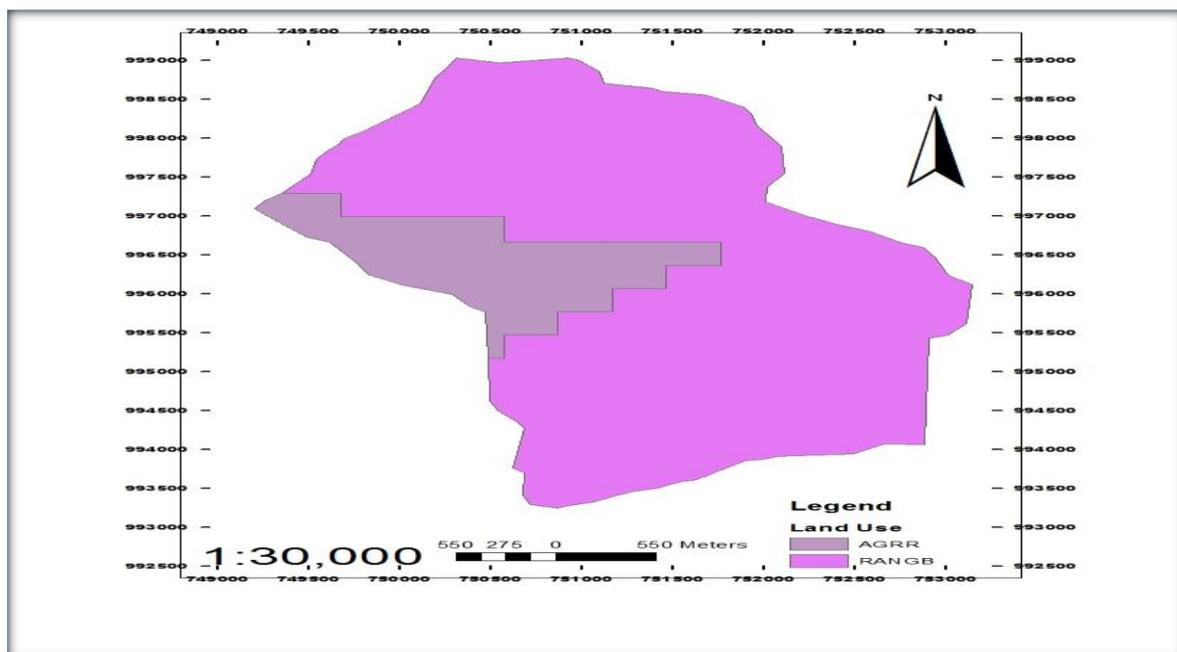


Figure5- 3: Land use and cover of Fir Kabso SSIP Watershed

5.1.7. Soils of the study area

Soil data is one of the major inputs for watershed management study with inclusive of physical and chemical properties. The Soil Map of the study area was obtained from Ethio soil Map. Then, map of the study area was clipped using of ArcGIS 10.4 spatial tool.

Most of the soils in the study area are moderately deep to very deep with the exception of the miscellaneous land on very steep slope. Relatively moderately deep soils have been observed in steeper slopes, while deeper ones have been observed at flat to moderately steep slopes. In the study area, most of the soils are dominated by fine to medium texture. The red soils occurring in the study area are known to have, fine textured clays with good tilth and good permeability.

**Table5- 5: Area Distribution of the soil types within in the watershed**

No	Soil types	Area	
		ha	%
1	<i>Eutric Cambisols</i>	792	61.6
2	Rendiznas	493	38.4
Total area		1285	100

5.1.7.1. *Eutric Cambisols*

Cambisols have a cambic B-horizon or a deep umbric A-horizon. Those with only an umbric A-horizon are called Humic cambisols. These similar to the Phaezems, only they have an umric A horizon. Cambisols base saturation of less than 50 percent is Dystric cambisols. Most cambisols are limited to the agricural value, as they occur dominantly on slopes are often shallow or have many stones or rock outcrop. Where cambisols are deep and not stony, they are good for agriculture.

5.1.7.2. *Rendiznas*

Thèse soils have a mollic A horizon over calcareuse rock material. Their agricultural value is limited becuase generall the root zone Is Small and There are many stone and rocks outcrop.

Rendiznas is the soil with initial stage of soil formation, found at initial stage of profile development marked by changes in soil structure, color and texture in the sub-soils or weakly developed soils relating to their parent material. Beginning transformation of soil material is evident from weak, mostly brownish discoloration and/or structure formation below the surface horizon.

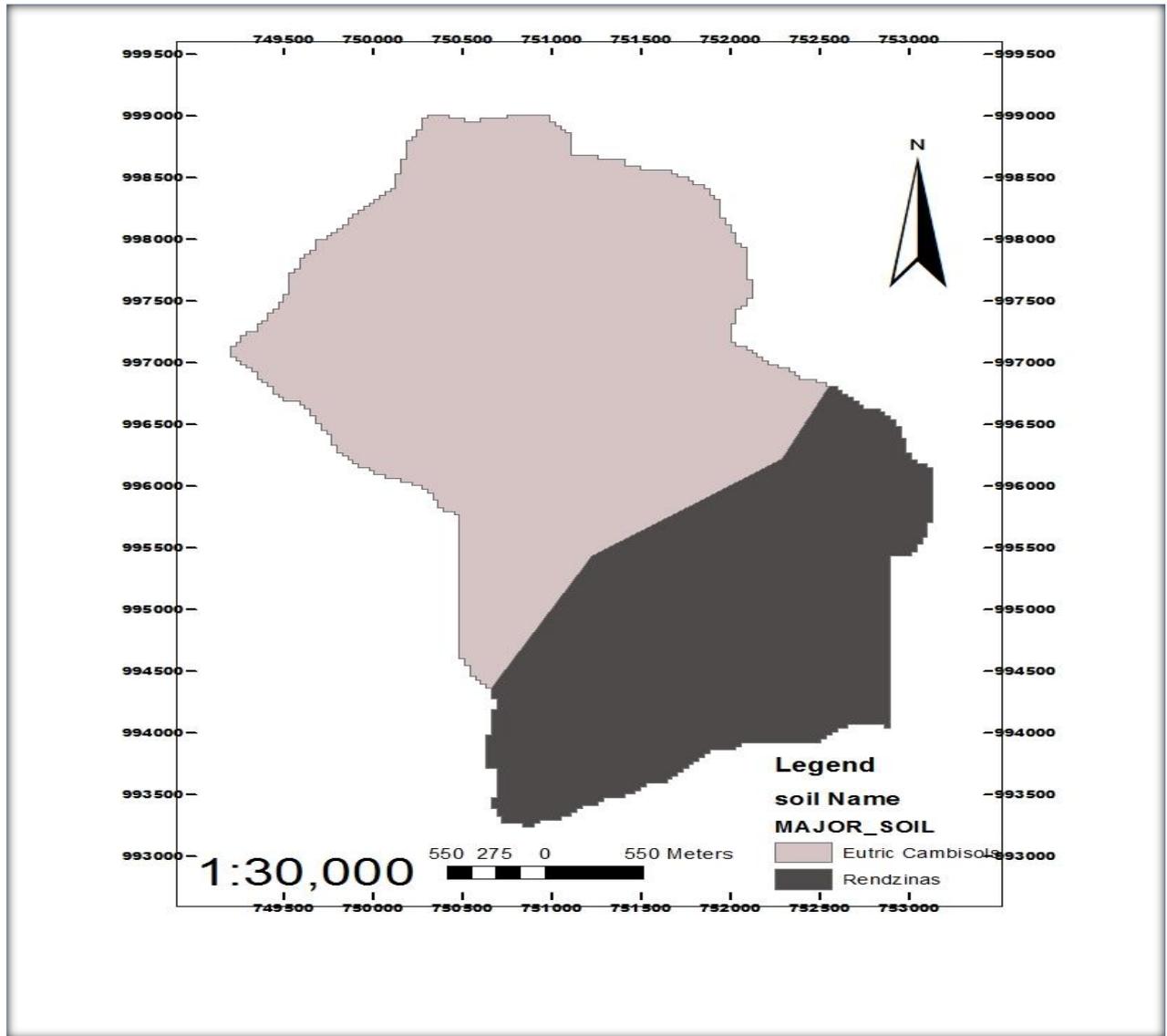


Figure 5- 4: Soil Map of Fir Kabso SSIP Watershed

## 6. EXISTING SOCIO–ECONOMIC CONDITION, AGRICULTURAL AND SWC ACTIVITIES

### 6.1. SOCIOECONOMICS

Socio-economic information helps to prioritize the main problems of the community in proposing acceptable and technically sound watershed management interventions. Sometimes the top priority of the community may be beyond the objectives of the project. In such cases, integrated and multi-disciplinary approach would be a good solution.

The Socio-Economic situations of the study area were collected from the respective Woreda Office of Agriculture with predefined format, discussion with experts and development agents. Moreover; site observations were carried out in the watershed across the watershed to get clear picture on the socio-economic aspects of the study area.

#### *6.1.1. Farming System and Crop Production Practices*

The farming system in the watershed area is mainly characterized by traditional agricultural practices. The area is experienced with lowland cereals based mixed farming system. This farming system is dominated by lowland cereal crops like maize, sorghum, haricot bean.

#### *6.1.2. Source of Energy*

Group discussion, revealed that almost all population in the watershed are using biomass and natural wood as the principal energy source, with the main sources include, maize and sorghum residues and other indigenous trees and bushes. Fuel wood is a problem during the rainy season. Most of the time female and children are responsible to collect fuel wood. Fuel wood consumption is increasing parallel with population growth, which leads to environmental degradation and aggravates soil erosion. The results of group discussions indicate the community in the watershed does not use improved fuel saving technologies or other alternative energy sources.

#### *6.1.3. Land Holding or tenure*

The average land holding is 1.25 ha, but majority of the land situated in sloppy areas is not suitable for cultivation and grazing. Mainly almost all the upper part of the watershed is found in a very sloppy area.

#### *6.1.4. Cropping pattern*

Cropping pattern practices are dynamic and determined by the interaction of a set of physical, socio-economic and cultural factors. Among several cropping systems, farmers in this study area practice crop rotation to improve the fertility of farmland as well as to minimize weed, pest and disease infestation.

As per the result obtained during consultation session, monoculture/mono-cropping is the dominant cropping pattern in the watershed, however mixed cropping is rarely practiced in field crops like maize grown with haricot bean. Nevertheless, majority of farmers are undertaking mixed and inter cropping system in the homesteads. Except Maize, other crops are planted in broadcasting method. Unlike row planting, broadcasting worsens soil erosion. Majority of farmers in the watershed do not use compost as alternative source of fertilizer particularly for field crops.

#### *6.1.5. Major Livelihood Options*

The survey team has identified major livelihood options in the watershed. The group discussion has revealed that almost all farmers exclusively engage in on-farm activities and undertake little off-farm activities. However, off-farm activities such as selling of fuel wood are rarely practiced in the watershed. Crop production and animal rearing are the main on-farm activities. Among on-farm activities field crop production, fruit and tree production in the homestead are the main livelihood intervention, whereas vegetable production is practiced by very few farmers. Similarly, cattle rearing and goat production are the dominant animal production systems undertaken in the watershed.

Even though there are gaps, farmers in the watershed have been trying to diversify household income by implementing a portfolio of on-farm activities.

As indicated above a small number of farmers in the watershed rarely undertake selling of fuel wood, which could be categorized as off-farm. Results obtained from the field survey indicated households involved in diversified livelihood activities relatively have better family income.

#### *6.1.6. Existing Soil and Water Conservation Activities*

In the study area, conventional SWC practices have been practiced in varying extent with mass mobilization. The common introduced SWC practices are farm terraces (soil bund, stone bund), cut off drain, waterways and check - dams, and the like. As the study area is located in high

rainfall area, the common features of all introduced SWC measures are to retain and /or infiltrate excess run-off so that overland flow will be reduced, consequently, control soil erosion that might wash away through the surface flows. They also practiced SWC measures that are used to divert run-off to protect down slope lands. Table 6-1 gives biological SWC activities in the Woreda.

**Table 6-1: Biological soil and water conservation intervention in Malka Balo wereda**

Type of trees	Number
Erythrina abyssinica (Qorch)	1235
Cordia Africana ( wenza)	780
Croton mynhancia (bisana)	970
<i>Accacia spp</i>	3000
Albiziaa chinperianc (sesa)	1055
Fruit trees	2081

Source: Malka Balo woreda Agriculture & Natural Resource office

The data obtained from Malka Balo wereda indicate that on limited tree species are planted for the purpose of soil conservation. The figures indicating that the soil and water conservation interventions have not been practice at required level to protect the watershed and surroundings.



**Figure 6-1: Soil conservation structures existing on farmland**

As observed during the field observation the integration of physical and biological SWC measures are limited. Furthermore, the sustainability of the introduced SWC measures is poor due to various reasons. As per the information obtained from WoA, some of the implemented physical SWC measures could not sustain and provide the envisaged objectives. The main reasons to this failure were:

- Improper farming operation, unwillingness of farmers
- Free grazing system,
- High runoff and flooding,
- Lack of integration of biological SWC measures; and
- Lack of maintenance and upgrading works.

In this study area, as a good practice farmers kept scattered natural trees on cultivated land as a traditional agro-forestry integrated in the farming system. The number of trees retained on cultivated lands per hectare varies from place to place. These need to be protected and managed so that they make the maximum contribution to soil and water conservation and soil fertility

## 7. EROSION HAZARD ASSESSMENT

### 7.1. GENERAL

Soil degradation by water erosion is a serious problem in the watershed. The soil erosion process is influenced by biophysical environment comprising soil, climate, topography and ground cover and interactions between them. Soil erodibility; susceptibility of soil to agent of erosion - is determined by inherent soil properties e.g., texture, structure, soil organic matter content, clay minerals, exchangeable cations and water retention and transmission properties. Climatic erosivity includes drop size distribution and intensity of rain, amount and frequency of rainfall, run-off amount and velocity, and wind velocity. Terrain characteristics that influence soil erosion are slope gradient, length, aspect and shape. Ground cover exerts a strong moderating impact on dissipating the energy supplied by agents of soil erosion. Furthermore, the effect of biophysical processes governing soil erosion is influenced by economic, social and political causes.

### 7.2. CAUSE OF SOIL EROSION

The main causes of soil erosion in the study area were:

- Improper land use practices;
- Deforestation & loss of vegetation;
- Overgrazing due to free grazing system;
- Increased human and livestock population pressure ;
- Limited use of SWC measures;
- Improper disposal of runoff through traditional ditches;
- High seasonal runoff.

Steep topography, erodible nature of the soil type and seasonally abundant rainfall in the months of June, July and August were other major contributing factors for the present situation in the study area.

Lastly, but important, the rapid increase of population and uncontrolled cutting of trees and shrubs for various purposes, notably firewood, charcoal, timber, expansion of cultivation and the like were also the major aggravating factors to the present situation.

Therefore, appropriate and timely measures shall be taken to reverse the situation, and maintain the available vegetation resources in the area. If not, this will result to substantial loss of the remaining vegetation resources, increased deforestation and soil erosion and consequently total loss of land productivity and undesirable environmental consequences .

### **7.3. EFFECT OF SOIL EROSION**

**Loss of Soil Mass:** Soil erosion is by far the largest process causing land degradation, in the watershed. The mass of soil wasting from sheet, rill, gully and streams is often assessed as the amount of soil material that has been removed from a landscape by water, since these physical changes are obvious and quantifiable. The total amount of physical soil loss in the watershed was that causes of land and soil degradation. Due to the poor soils, the process of restoring badly degraded areas will inevitably be difficult, slow and expensive.

**Nutrient Loss:** Degradation of the soil resource, on the other hand, has been reported alarming; soil productivity is declining at the rate of 2-3% per year (Hurni, 1993) with soil erosion rate in most croplands usually being far beyond the rate of formation due to cultivation of steeply sloping lands without adequate SWC measures.

The capacity of the soil of the watersheds to produce crop is greatly reduced. Soil from the top layer is the most concern because it contains more organic matter rich in available plant nutrients. This soil is lost in sheet and rill erosion nutrients which are of great value in containing Nitrogen, Phosphorus and Potassium. The productivity of crop land is decreasing year after year at alarming rate. Land productivity is decreasing. The higher yield in production is associated with fertilizer application, improved seeds and farm expansions from other uses.

Loss of soil fertility is severely affected by soil erosion, soil and organic matter burning, through limited recycling of dung and crop residues in the soil (use of dung and crop residues for household fuels and animal feeds) and decline in fallow periods. Even though the farming system in the catchment area is mixed, crop–livestock, the culture is based on the nutrient take way from the soil that the nutrient return to the soil is minimal.

**Hydrological Degradation:** Hydrological degradation that include surface and subsurface water declines, seasonality of discharges of the Springs, variability of rainfall, etc. are important

causes and consequences of the processes of land degradation and challenges for the sustainable land management systems in the sub-basin.

**Sedimentation:** Proposed infrastructure will be collected sediments from all parts of its watersheds. There are more pressures and interest conflicts on the infrastructures aggravating sediment loads to it. Options that minimize the current picture of degradation are important and shall be assessed and introduced. Reservoirs and canals, at headwork and within the command area, fill with sediment the intended achieving to the targeted goal will be less likely.

All these forms of degradations mentioned above (i.e. sheet and rill erosion, gully erosion, stream/River bank erosion and sedimentation) need proper interventions. These rooted problems of land and watershed degradation will be tackled if proper, holistic, and comprehensive land management interventions in watershed logic are applied. All necessary interventions in a ridge-to-valley or watershed logic approach all the way starting from micro to macro level have to be applied on quality basis

#### 7.4. ESTIMATION OF SOIL LOSS

The main cause of land degradation of the command area is soil erosion, which is basically known to be caused by high runoff from the Fir Kebso watershed. With the objective of pointing out the main erosion sites within the watershed, the extent and cause of erosion and suggest possible corrective measures, the watershed is classified into micro-watershed and the erosion status of each unit computed employing the USLE (Universal Soil Loss Equation) soil loss prediction equations so called as USLE erosion model as adopted to the Ethiopia context. The soil loss of the Fir Kebso watershed is computed employing the following USLE equation.

Mathematically the equation is denoted by  $A = R * K * L * S * C * P$ .

Where:

A = soil loss in tons per hectare per year

R = rainfall erosivity factor

K = soil erodibility factor

L = slope length factor

S = slope gradient factor

C = land cover factor

P = conservation practice factor

The main factors involve in the USLE are rainfall (R), soil erodibility (K), slope (LS) and ground cover and other interventions (C, P). Out of these factors, the key factor is land

management (factors C and P) as it is the only factor which can be easily manipulated. Others are inherent characteristics of an area

For Ethiopian conditions, the applicability of the USLE model was studied by Hurni under SCRCP (Hurni, 1985). Based on his research findings, Hurni gave modified values of parameters used for the computation of annual soil loss rate in small plots. Ideally the parameter criteria need to be adapted (through experiment) to local situations. For this reason, the Soil Conservation Research Project (SCRCP, 1996) has developed factors data.

*7.4.1. Rainfall Erosivity (R) Factor*

Rainfall erosivity is a term used to describe the degree of soil loss from cultivated fields due to rainfall effect when other erosion parameters are constant. Erosivity is measured in Mega joule-cm per hectare-hour (MJ-cm/ha-hr). Rainfall erosivity (R) is computed from hourly, daily, monthly or yearly time series rainfall data. Wischmeier and Smith (1978) reported that R values computed from the maximum rainfall of 30 minute intervals (I30) of a storm gave best estimates of erosivity. The energy of a rainfall event is the product of the amount of rainfall and its intensity. However, the data on 30-minute rainfall have constrained the direct application of the model in estimating R factor. Therefore, the model adapted by Hurni for Ethiopian conditions based on the available mean annual rainfall data P has been used for this study. It is given by the regression equation:

$$R = -8.12 + 0.562 * P$$

Where: P is the annual rainfall (mm).

*7.4.2. Soil Erodibility (K) Factor:*

Some soils erode more easily than others do even when all other factors are the same. This difference is termed soil erodibility and is caused by the properties of the soil itself. The K-Factor is defined as the soil loss rate per erosion index unit for a specified soil as measured on a unit plot. The Ethiopian SCRCP adapted the K- factors based on the top soil color as black, brown, red and yellow color types. Accordingly, the K-Factor values for the study ranges from 0.15 to 0.20 depending the major soil types of the study area.

Soil color	Black	Brown	Red	Yellow	Grey	White
K factor	0.15	0.2	0.25	0.3	0.35	0.40

7.4.3. Slope Gradient and Slope Length (LS) Factors

Among the four major factors, topography is relatively stable which can remain constant over time. In the present soil erosion study slope-length and slope steepness are used to reflect the effect of topography on erosion.

**Table 7-1: Combined Slope Length and Gradient Factor**

Slope Gradients (%)	Mean LS Factor
0-8	0.55
8 – 15	2.1
15-25	3.9
25-35	7.2
>35	13.94

Erosion is influenced by the slope gradient and length of the land, the potential erosion on uniform slopes increasing as these parameters increase. On steep and long slopes, the down slope splash by rainfall is higher, and water movement is faster, resulting in a higher kinetic energy of water to erode the soils. The effects of slope gradient and length have been discussed in many reports. In order to estimate the potential erosion hazard, the determination of these factors is crucial. The values of the LS factors are calculated for a given area, using the following formulae for a range of slope gradient (Wischmeir and Smith, 1978).

7.4.4. Crop management (C-values) factor

The crop management factor represents the ratio of soil loss under a given crop to that of the base soil. The cover management factor (C-values) reflects the effect of cropping and management practices on the soil erosion rate. It is used to determine the relative effectiveness of soil and crop management systems in preventing soil loss. The C- value is a ratio comparing the soil loss from land under a specific crop and management system to the corresponding loss from continuously fallow and tilled land. This is the cover management parameter and it ranges between zero (ideal case when there is no soil loss) and one, corresponding to the greater amount of soil loss. This dimensionless factor measures the ratio of soil loss between a specific area with given cover management conditions and an experimental plot under reference conditions "clean tilled continuous fallow conditions".

**Table 7-2: C Factor Values Used to Predict Erosion Hazard**

Land Use/Land Cover Type	C_ Factor
Lake	0
Dense acacia species bush land	0.001
Dense acacia species shrub land	0.001
Town	0.003
Open acacia species bush land	0.01
Open acacia species shrub land	0.01
Shrub Grass Land	0.01
Riparian wood	0.03
State farm	0.65
Exposed rocky surface with scattered shrub	0.05
Exposed sand and soil surface with scattered shrub	0.05
Open Grass Land	0.1
Private Ranching	0.1
Sugar cane plantation	0.12
cultivated land	0.65

Source; Modified based on Hurni (1985)

#### 7.4.5. Conservation practices (P-Values)

The management practice factor P indicates the effect of conservation practices on soil erosion, where in the land that has adequate conservation interventions will have a lower P factor value, i.e. a lower degree of erosion. The value of P factor ranges between zero and one: zero indicates that the land is perfectly protected while one indicates the condition in which farming is along the slope of the land. This is the only farming practice that increases erosion instead of reducing

it. Most commonly used values of P factors for different management practices are given in table 7-3.

**Table 7-3: Management Factor Values**

Management /conservation measures	P value
Ploughing up and down slope	1.0
Contour ploughing	0.9
Applying mulch	0.6
Strip cropping	0.8
Inter cropping	0.8
Grass strips	0.8
Bunds, good shape	0.7
Bunds, degraded	0.9
Broad-based bench terrace good shape	0.01
Bench terraces, narrow-based, degraded	0.9
Contour stone bunds/lines at wide spacing (20-50 m)	0.7
Contour stone bunds/lines at narrow spacing (10-15m)	0.5
Terraces on more than 80% of the croplands	0.60
Terraces on 50-80% of the croplands	0.75
Terraces on 30-50% of the croplands	0.85
Terraces on less than 30% of the croplands	1.00
Complex of natural terraces and non-terraced lands	0.50

Source: Hurni 1985

According to the calculation, the annual soil loss of the study area was estimated to be within the ranges of the 0 to 59 ton/ha/yr. These annual soil losses rated as none (0-10%), slight (10-15%), and moderate (15-50%), high (50-100)

**Table 7-4: Estimated annual soil Loss of the watershed**

No	Severity Stage	Annual soil loss (ton/ha/yr)
1	Low	0-4
2	medium	4-15
3	high	15-59

The USLE result discussed in here are soil losses from sheet and rill erosions and does not include soil losses from other erosion types. As mentioned in the table above, the result shows that the annual soil loss in the watershed reaches up to 59 ton/ha/yr. According to these results 40% of the study area is classified under moderate, high and very high erosion classes with annual soil loss of greater than 10 ton/ha/yr, which require urgent action for conservation. Whereas, annual soil losses lower than 10-ton /ha/yr are within the tolerance level. Rose (1994) established annual soil loss tolerable limits to 10t/ha/yr for tropical region.

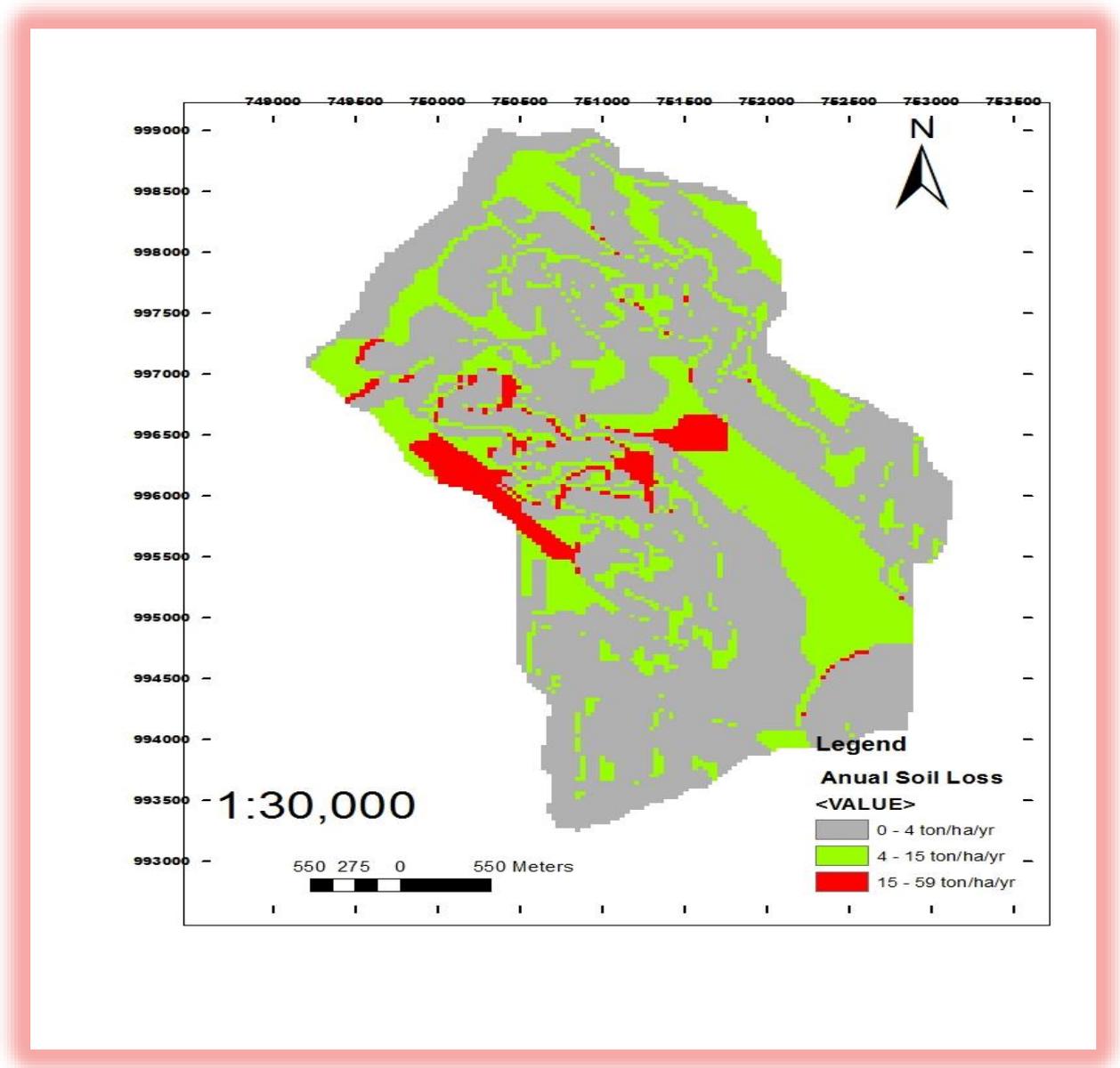


Figure 7-1: Map of the Annual Soil loss of the Watershed

---

## 8. HYDROLOGICAL AND SEDIMENT YIELD ANALYSIS

### 8.1. FLOOD ESTIMATION

The entire watershed drains to Fir Kebso Spring, which originates from high lying areas, and empties to the command area. Fir Kebso Spring has less tributaries that originate from the highlands upstream of Fir Kebso Watershed. All the streams are not protected and in many cases needs further development of the streams. This could help increase the stream discharges during dry months.

Various types of flood estimation methods area available depending on the size of the catchment area:

- for catchment area less than  $0.5\text{km}^2$ = Rational Method
- for catchment area greater than  $0.5\text{km}^2$  = The United States Soil Conservation Service method (SCS)

Since the size of the watersheds upstream of the proposed sites is greater than  $0.5\text{km}^2$ , the SCS method was used. Accordingly, the procedures used in Estimation of the peak flood for various return periods are indicated below:

### 8.2. DATA AVAILABILITY AND PROCEDURES

For any hydrologic analysis, it must be recognized that there are many variable factors that affect flood discharges. Some of the factors that need to be recognized and considered on flood estimation are the following:

- Rainfall amount and distribution;
- Catchment area size, shape and orientation;
- Ground cover;
- Type of soil;
- Topography ;
- Antecedent moisture condition etc...

The above data were collected from various sources. In addition CN and rainfall intensity for various return periods were derived from Ethiopian Road Authority Drainage Design Manual (ERADM, 2002).

**Curve Number (CN):** CN is a measure of the runoff potential of the catchment and is determined from land use and cover condition, soil type. The standard SCS curve number is taken from Ethiopian Road Authority Drainage Design Manual (ERADM, 2002). The catchments boundary, soils and land cover maps are overlaid using the GIS function tools to determine CN for each catchment. Subsequently, the CN of each catchment is determined correspondingly to the land cover condition and soil hydrological groups. As the catchments have various land use types, a composite CN is calculated and used in the analysis.

**SCS Method:** This method was developed by the U.S soil conservation service. For calculating the rates of runoff, the method requires the same basic input as the Rational Method. The SCS approach, however, is more sophisticated in that it considers also the time distribution of rainfall, initial rainfall losses to interception and depression storage, and infiltration rate that decrease during the course of a storm.

**Direct Runoff Estimation:** The SCS methods produce the direct runoff for a storm by subtracting infiltration and other losses from the total rainfall. A rainfall-runoff relationship is used to separate total rainfall into direct runoff, retention and initial abstraction utilizing the following equations:

$$Q = \frac{(P - Ia)^2}{(P - Ia)} + S$$

Where: Q = accumulated direct runoff, mm

P = accumulated rainfall (potential maximum runoff), mm

I<sub>a</sub> = initial abstraction including surface storage, interception, and infiltration prior to runoff, mm

S = potential maximum retention, mm

The empirical relationship used in the SCS runoff equation is: I<sub>a</sub> = 0.2S

Substituting 0.2S for I<sub>a</sub> in equation above, the SCS equation becomes:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

Where:

P= depth of rainfall for a 24 hour duration of the relevant frequency.

S= potential maximum retention

The ‘S’ value is related to the soil and cover conditions of the catchment area through the CN, which can be determined by:

$$S = 1000 / (CN - 10)$$

The curve number (CN) is an index expressing a catchment’s storm flow response to a rainfall event. The catchment’s characteristics considered in determining its CN are:

- Hydrological soil properties
- Land cover properties (including land use, its treatment and hydrological condition) and
- The soils in the catchment relative wetness or dryness just prior to the rainfall event.

**SCS peak discharge equation:** The calculation of peak discharge by SCS techniques is based on the triangular unit Hydrograph (UH) concept

Where:

$$Q_p = \frac{0.2083AQ}{T_c^{0.5} + 0.6T_c}$$

Q<sub>p</sub> = Peak discharge (m<sup>3</sup>/s)

A = Catchment Area (km<sup>2</sup>)

Q = Storm depth (mm)

T<sub>c</sub> = Time of concentration (hr)

**Time of concentration:** The time of concentration (T<sub>c</sub>) is an index of lag frequently used to define a catchment’s response time. Time of concentration is the time taken for runoff to travel from the hydraulically most remote point of the catchment to the point of outlet. One of the most used empirical equation to calculate time of concentration is the Kirpich equation (1940), given by:

$$T_c = \frac{0.0195 \left( \frac{L}{S^{0.5}} \right)^{0.77}}{60}$$

Where: T<sub>c</sub> = time of concentration (hr)

L = the length of the catchment’s along the longest spring channel (m)

$S =$  the overall catchment's slope in  $m/m = \Delta H/L$

$\Delta H/L =$  the difference in elevation between the most remote point and the outlet point

Accordingly, the parameters used and the result of flood estimate is presented below with a series of Tables.

**Table 8-1: Maximum storm value (mm) in 24 hrs for T year's returns period**

Return period	2 year	5 year	10 year	25 year	50 year	100year
Storm(mm)	65	84	98	118	132	147

Source: ERA drainage design manual (2002)

**Table 8-2: Parameters for each watershed upstream of the proposed site**

Micro-watershed	CA (km <sup>2</sup> )	Length (m)	Elevation -Max(m)	Elevation Min(m)	Elev. difference(m)	Slope (m/m)	Tc (hr)	CN	S	la
Fir Kebso upper	7.9	4955	2245	1728	517	0.10	0.39	80	63.5	12.7
Fir Kebso Lower	4.95	3698	1828	1495	433	0,11	0.57	80	63.5	12.7

**Table 8-3 : Peak flood estimated for Free Kebso Spring by SCS method**

Return period	5	10	25	50	100
Peak flood (m <sup>3</sup> /s)	16.77	21.73	28.36	33.49	38.71

As indicated by the figures in the tables there is considerable potential for small-scale irrigation development by harvesting the runoff or developing the existing water resources. It has also a potential in surface water resources from many small temporary springs in the watershed area. However, most of the farmers within this watershed are using limited the water harvesting technologies and practices for their crop production, which is mainly due to lack of knowledge, low extension systems in the area and poor financial capacity of the farmers. Moreover, most of the population of this watershed area use un-protected water sources and share with livestock and wild animals due to lack of safe water supply.

### 8.3. SEDIMENT DELIVERY RATIO COMPUTATION

The SDR is a preferred method to estimate the delivery of sediments to downstream receptors, the Fir Kebso Spring in the current case. The SDR is used to estimate the total sediment transported to the Fir Kebso Spring then to the diversion site.

The values of the SDR are also affected by Watershed physiographic, sediment sources, transport system, texture of eroded material, land cover, etc. For this study, simple empirical formula was used to determine the sediment delivery ratio of the study watersheds at different outlets system. The empirical equation is given by:

$$SDR = A^{-0.125}$$

Where,

A is the drainage area (ha),

SDR is sediment delivery ratio (-)

The following table shows the calculated sediment delivery of each watershed system.

**Table 8-4: Sediment deliver ratio and estimated annual sediment yield at each drainage outlet system**

No	Micro-watershed	Drainage area (ha)	SDR	Estimated point soil losses (ton/ha/yr)	Estimated Annual sediment yield (ton/ha/yr)
1	Fir Kebso Upper	790	0.43	35	15
2	Fir Kebso Lower	495	0.46	28	13

Accordingly, the SDR at the watersheds outlet systems are 0.43, and 0.46 that means about 43% and 46% of the annual soil loss reaches at the outlet point at each micro-watershed watershed system.

Then, the sediment yield reaching the outlet of each micro-watershed was calculated using a formula given by:

$$Q_s = E * SDR$$

Where,

Qs = sediment yield (ton/ha/yr);

E= estimated point soil losses (ton/ha/yr);

The variations are may be due to the complex nature of the watersheds and soil erosion process in estimating soil loss and sediment yields from the catchment. As can be indicated above that the sediment yield reaching to the outlet of the watershed system is lower than the estimated soil loss. This can have hydrological justification. That is the shape of the study area has a concave shape slope where large portion of the soils washed away from the upper watershed may be deposited rather than reaching to the outlet points. However, this does not mean that the sediment load from the springs is low.

Therefore, integration of watershed management is not questionable for this study area as one of the environmental management component to ensure the sustainability of to be development schemes.

---

## 9. WATERSHED DEGRADATION AND MAJOR PROBLEMS OF THE WATERSHED

### 9.1. WATERSHED DEGRADATION

Land degradation is a process of losing the land's potential, which is caused by combined processes of both the natural phenomenon and human interference interchangeably or simultaneously. Inappropriate agricultural practices that are not in harmony with the biophysical environment, overgrazing, and destructing the vegetation cover, are some of the human actions significantly contributing to land degradation. The most common causes of land degradation in the Fir Kebso watershed include but not limited to-

- Poor farming practices which involve cultivation in steep slopes, marginal lands and absence of conservation practices
- Overgrazing
- Over cultivation of cropland
- Forest and bush degradation
- Deforestation for expanding cultivation

The status and degree of soil erosion were noted during field survey. Based on the result of assessment two types of erosions were observed in the study area, sheet and rill. Sheet erosion is the most frequently observed in the study area and they are formed going down the slopes against contours.

Development in Fir Kebso watershed is challenged by multiple problems, with each posing its own management challenge. First, the natural resources base is under intense pressure from population growth and erosion-inducing traditional farming and management practices. Second, farming communities face severe constraints related to intensive cultivation, overgrazing and deforestation, soil erosion and soil fertility decline, and demand for livestock feed, and fuel wood. Third, climate change and poverty are already contributing to these challenges. These challenges have contributed to a decline in yields in some areas..

## 9.2. MAJOR WATERSHED PROBLEMS

The goal of this study is to promote sustainable livelihoods among the communities within the watershed by employing various development interventions. Another critical impact anticipated from the study is contribution to the establishing sustainable ecosystem in the area.

Moreover, to identify the major socio-economic problems of the watershed, the study team employed group discussion with multi-disciplinary woreda experts and officials based on the pre-prepared questioners. During the discussion period, the watershed development experts were actively participated in the identification of main problems in “Fir Kebso” watershed. The discussion session were started after brief introduction of the study objectives. The watershed development expert identified major problems and put solutions based on severity by employing preference ranking. Accordingly five major problems were identified: agricultural (basically crop) yield reduction, soil erosion, deforestation, lack of awareness and distance of water for human and animal during dry season respectively.

When the problem of land use are perceived in terms of man in relation to land, the relatively high density of population and its implication to current land use as well as future potential in the watershed of Fir Kebso watershed, come to the fore front. The implication of the high density of population & density has to be seen in terms of the availability of land resources not only to sustain the existing but also the expanding population.

### *9.2.1. Productivity and Production Decrease*

According to the result obtained from preference ranking that is done by the watershed development expert, yield reduction is the dominant constraint triggered by soil erosion, poor community awareness and uncertainty in using improved technologies (seeds, fertilizers, compost, and agronomic practices), weed and pest. However, soil erosion contributes the lion share for the yield reduction. On the other hand, experts realize that soil erosion is caused by overgrazing, improper land use and poor farming practices. As we confirmed during transect walk along the accessible road and discussion held with the watershed development expert, very sloppy lands have been in use for cultivation and grazing. Consequently, yield reduction is sever in the upstream part of the watershed as compared to the downstream due to the sloppiness of the area which aggravates soil erosion, since soil erosion and declining farm income have strong correlation. In other words yield reduction is increasingly intertwined with soil erosion and

deforestation. Other fertility building practices like crop rotation especially grain legumes are not practiced fully.

### *9.2.2. Deforestation*

As per the preference ranking employed by the wereda experts, deforestation is the second dominant problem in Fir Kebso watershed. Coupled with others, the main driving force for deforestation are lack of alternative energy source, population growth and overgrazing

It was observed that in some places, most important indigenous trees were almost cleared and remained with some open mixed wood land in rugged topography and following the Spring courses where in accessible for crop production. Currently, livelihoods of many people are depending on forest resources/products. Consequently, at present there is increasing rate deforestation in the study area.

### *9.2.3. Soil Erosion*

Soil erosion is the most widely spread and most serious land degradation feature in the sub-basin mainly associated with improper agricultural practices, deforestation and over-grazing: The rugged landscapes of the upper part of the watershed are contributing the major sediment input to the spring and will be in turn to the reservoir.

The land degradation resulting in reduced productivity has significant impact on GDP (reduces up to 5%). Both 'on-site' reduced productivity and 'downstream' sedimentation have negative multiplier effects on the national economy with high social as well as economic costs. There are a number of small community watersheds contributing runoff and suspended soil sediment to these major springs. The study is part of the watershed development and rehabilitation program of the watershed with the objective of minimizing the sediment load entering into these springs and their tributaries.

River bank erosion is severe, widespread, and alarmingly serious in this part of the watershed. River bank erosion is increasingly becoming an enormous challenge for many of the farmers in the study area and in many parts of the country. It takes away productive agricultural lands. It is a serious socio-economic problem and a major challenge for the rural development programs particularly in the central highlands where 65 to 85% of the incomes of the communities come from agriculture particularly crop production alone. Protecting the farm lands from such menace; soil erosion and particularly from the damage by River bank erosion is a priority and a

legitimate concern for the planners, decision makers and extension workers. The soil sediment from these small community watersheds in the watershed and elsewhere in the country are increasingly becoming, not only at the site, but it is also a treat to waters resources and infrastructure downstream (off-site effects) such as dams, reservoirs, water treatment plants and for the investment and development corridor and the lake and its aquatic ecosystem in general.

#### *9.2.4. Capacity Gaps with Respect to effective Watershed Management*

The Federal and Regional governments have already created adequate policy environments to start with prevention the current land degradation threats associated with deforestation, overgrazing, improper land use practices and over exploitation of the resources. Policies, strategies and legislations related to agriculture, forest resources, water, biodiversity, land administration and environment, tourism, fishery are already in place. Therefore, the major capacity building gaps in realization of the above policy objectives to attain sustainable natural resources management in a watershed context could be technical, technological, knowledge, information institutional, implementation barriers, participation, and sectoral integration problems.

## 10. LAND CAPABILITY CLASSIFICATION

### 10.1. GENERAL

Land capability classification refers to a systematic arrangement of different kinds of lands according to those properties that determine the ability of the land to produce on permanent basis. Classifying the land according to its capability is a pre-requisite and vital for planning and implementation of watershed development programs. The land capability classification of the Watershed was made following the methodology developed by Escobedo (1988) to determine the soil conservation requirement class for Ethiopian conditions. The watershed was divided into different slope classes for each type of land use/cover and soil distribution, overlaying thematic maps of both land use/cover over slope class maps.

The USDA Land Capability classification System is used in evaluating the capability of Fir Kebso watershed. This system of evaluation is the most widely used method, though constructed for use in the US, now adopted in many developing countries. The system is based on two concepts: capability and limitation, where capability is the potential of the land for use in specified ways or with specified management, practices and limitations are land characteristics which have adverse effects on capability.

Limitations are further classified into temporary and permanent. Permanent limitations are those, which are difficult to manage or change, or demand high investment to do, such as slope gradient and soil depth, and temporary limitations are those that can be improved by ordinary land management techniques. Table 10-4 provides the summary of land capability class for each type of land use/cover with different ranges of slopes. Based on the analysis of these factors for each types of land use/cover together with the slope class range, a land capability map as shown in Figure 10-1 has been developed. Then, the most appropriate land capability classes or groups are assigned.

### 10.2. CRITERIA FOR LAND CAPABILITY CLASSIFICATION

Land Capability Unit (LCU) is the lowest category of the system with the major limiting factors divided into lower unit and affecting the use of the land for agricultural purposes.

The corresponding factors that determine the land capability classes of the units are slope gradient (L), depth of soil (D), past erosion (E), water logging (W), infiltration (I), Topsoil texture (T) and surface stoniness or rockiness (S).

**Table 10-1: Classes of the Limiting Factors, Range Of Values, And Coding For Different Factors**

No	Slope class (L)	Range (%)	Code
1	Flat or almost flat	0-3	L1
2	Gently sloping	3-8	L2
3	Sloping	8-15	L3
4	Moderately steep	15-30	L4
5	Steep	30-50	L5
6	Very steep	>50	L6
	Soil depth classes (D)	Range in (cm)	Code
1	Very deep	>150	D1
2	Deep	100-150	D2
3	Moderately deep	50-100	D3
4	Shallow	25-50	D4
5	Very Shallow	<25	D5
	Erosion classes (E)		Code
1	None		E1
2	Slight		E2
3	Moderate		E3
4	Sever		E4
5	Very sever		E5
	Soil texture classes (T)	Code	Common name
1	Sand	T1	Coarse
2	Sandy Loam	T2	Coarse

No	Slope class (L)	Range (%)	Code
3	Loam	T3	Coarse
4	Silt Loam	T4	Medium
5	Clay Loam	T5	Medium
6	Silt Clay Loam	T6	Fine
7	Heavy Clay	T7	Fine
	Infiltration Class (I)		code
1	Good		I0
2	Moderate		I1
3	Poor		I2
	water logging classes (W)		code
1	None		W0
2	Intermittently Waterlogged		W1
3	Regularly Waterlogged		W2
4	Swamps		W3
	Stoniness or rockiness (S)		code
1	< 15%		S0
2	15 – 30%		S1
3	30 – 50%		S2
4	50 – 90%		S3
5	>90%		S4

**10.3. HOW TO USE THE LAND CAPABILITY CLASSIFICATION TABLE AND DETERMINING THE SCRC**

The first step in carrying out of land capability classification is land surface characterization that includes slope, topsoil depth, past soil erosion, top soil texture, drainage condition, infiltration and rockiness/stoniness. The land resources data of the watershed area is presented below (Table 10-4). The soils characteristics data of the study area were determined from various sources such as Rivet valley Lake basin Integrated master plan Study (1997) and (EHRS, 1985). Moreover, field observation data was collected on past erosion condition of the study area. However, as actual soil survey was not carried out, it needs to be rechecked during the detail WSM planning for a specific condition. Accordingly, based on major soil types and slope classes prevalent to SCRC method, mapping units were identified and the analysis was made based on Escobedo table (Table 10-2). Then, the LCC map was produced using the GIS function directly by transferring the spreadsheet data to GIS attribute table.

The following are the major procedures used to carry out the land capability classification:

- Divide the watershed area into mapping units based on the slope class ranges and major soil types
- Determine the physical characteristics of the micro-watershed for each mapping unit
- Then, determine the land capability class unit by using the Escobedo land capability classification table

In this method, the parameter that pulls to the last column of the Escobedo table presents the soil SCRC of the mapping unit and the characteristic that pulls to the column is the major limiting factor for that mapping unit.

**Table 10-2: The Escobedo Land capability classification table re**

Limiting factor	Range of codes permitted in the column								
	1	2	3	4	1-4	5	6	1-6	1-6
Slope (L)	1	2	3	4	1-4	5	6	1-6	1-6
Soil depth (D)	1	1-2	1-2	1-3	1-4	1-3	1-4	1-5	1-5
Past erosion (E)	0	0	0-1	0-2	0-2		0-3	0-4	0-4
Top soil texture(T)	3-5	3-6	3-7	2-7	2-7		2-7	1-7	1-7
Waterlogging(W)	0	0	0-1	0-2	0-2		0-2	0-2	0-3
Infiltration (I)	0	0	0-1	0-2	0-2		0-2	0-2	0-2
Surface stoniness rockiness(S)	0	0-1	0-2	0-2	0-3		0-3	0-4	0-4
Soil conservation Requirement class (SCRC)	I	II	III	IV	VI		VII	VIII	V
Land use suitability	Land suitable for annual crops				Land suitable for grazing or perennial crops		Land suitable for forestry	Land not suitable for agriculture	Swampy areas, Spring bed

**10.4. SOIL AND WATER CONSERVATION REQUIREMENT CLASSES (SWCRCs)**

There are eight SCRCs, Namely; I, II, III, IV, V, VI, VII and VIII. The risk of erosion and requirement of conservation practices increases from classes I to IV and VI to VIII. Class V is a special case and is for wet lands.

SCRC symbol + Major limiting factor(s) = Land capability sub class (LCSC). Examples of LCU: IIL, IIIL, IVD, VIIE, VIIT, VIID, VW. Land Class Unit 1 is without any limitation. The Land Capability Classification for use in soil and water conservation also attempts to identify the most suitable land use for each SCRC. The following grouping could be used.

**Table 10-3: Soil conservation requirement class and suitable land use**

SCRC	Suitable land Use
I, II, III and IV	Land , suitable for annual crops
V	Wet land – regularly waterlogged, may be

	suitable for temporary grazing and rice
VI	Land suitable for perennial crops or grazing
VII	Land suitable for forestry
VIII	Land not suitable for agriculture

**Table 10-4: Land Capability Subclass computation results by micro-watershed**

Micro-watershed	Slope (%)	Soil depth (D)	Past erosion (E)	Texture (T)	Water logging (W)	Infiltration (I)	Surface stoniness (S)	LCSC	SCRC
Fir Kebso upper	3-8	D1	E0	F-M	W0	I0	S0	VIL	VI
	8-15	D1	E1	F-M	W0	I0	S0	IVLE	IV
	15-30	D1	E1	F-M	W0	I0	S0	IVL	IV
	30-50	D2	E2	F-M	W0	I0	S0	VIL	VII
	>50	D3	E4	F-M	W0	I0	S0	VIII E	VIII
Fir Kebso Lower	3-8	D1	E0	F-M	W0	I0	S0	IVL	VI
	8-15	D3	E2	F-M	W0	I0	S0	VLE	VII
	15-30	D2	E2	F-M	W0	I0	S0	IVLE	IV
	30-50	D3	E3	F-M	W0	I0	S0	IVL	IV
	>50	D3	E4	F-M	W0	I0	S0	VIII E	VIII

Based on the concepts land is classified in different capability classes, which range from I to VIII. Land classes I to IV are classified as capable for arable agriculture and V and VIII for non-arable uses. The land capability classes of Fir Kebso watershed is classified in this system and four of the eight classes are found in Fir Kebso with varying limitations. There are no class I and V categories in Fir Kebso watershed.

According to the classification system, Class I land has no, or only slightly permanent limitation or risk of damage, by which land in this class can be cultivated safely with ordinary good farming methods. There are no lands in Fir Kebso watershed, which fall under this class.

Class II consists of lands subject to moderate limitations in use, which is subject to moderate risk of damage. They differ from class I in that the land is undulating, sloping and is subject to erosion and occasional overflows. These soils may require special practices such as soil conservation, rotations, water control devices etc. There are some units of this category in Fir Kebso watershed, around all micro watersheds whose slope range 3-8%.

Class III lands are subject to severe limitations in use for cropland, owing to severe risks or damage characterized by rolling or strongly sloping topography, are subject to more erosion, moderate infiltration and low in fertility. The lands can be used regularly for crops provided they are given proper treatment. These lands are occurred in Fir Kebso watershed when the slope is 0-3 and 8-15%.

Class IV lands are composed of soils that have very severe permanent limitation or hazards, it used for cropland, characterized by moderately steep slopes and subject to severe erosion. The lands can be cultivated occasionally if handled with great care. These lands are common in all micro watersheds.

Class VI soils should be used for grazing and forestry, they are unsuitable for cultivation as they are steep. Grazing should not be permitted to destroy the plant cover. Such areas are found around within the slope range >35%.

Class VIII lands are subject to severe permanent limitations or hazards when used for grazing or forestry. They are steep and eroded. There are lands in Fir Kebso watershed, which fall in the category >50% slope and micro watershed Fir Kebso upper and Lower

In general, the major limiting factors of the land use in the study area are mainly, infiltration, slope and past erosion. According to this classification, the area is suitable for annual crop production, development of perennial crops, grazing land and fodder development and forest development with varying intensities. However, integration of appropriate soil and water conservation is important to almost all slope ranges to reduce erosion and sustain the productivity of the area.

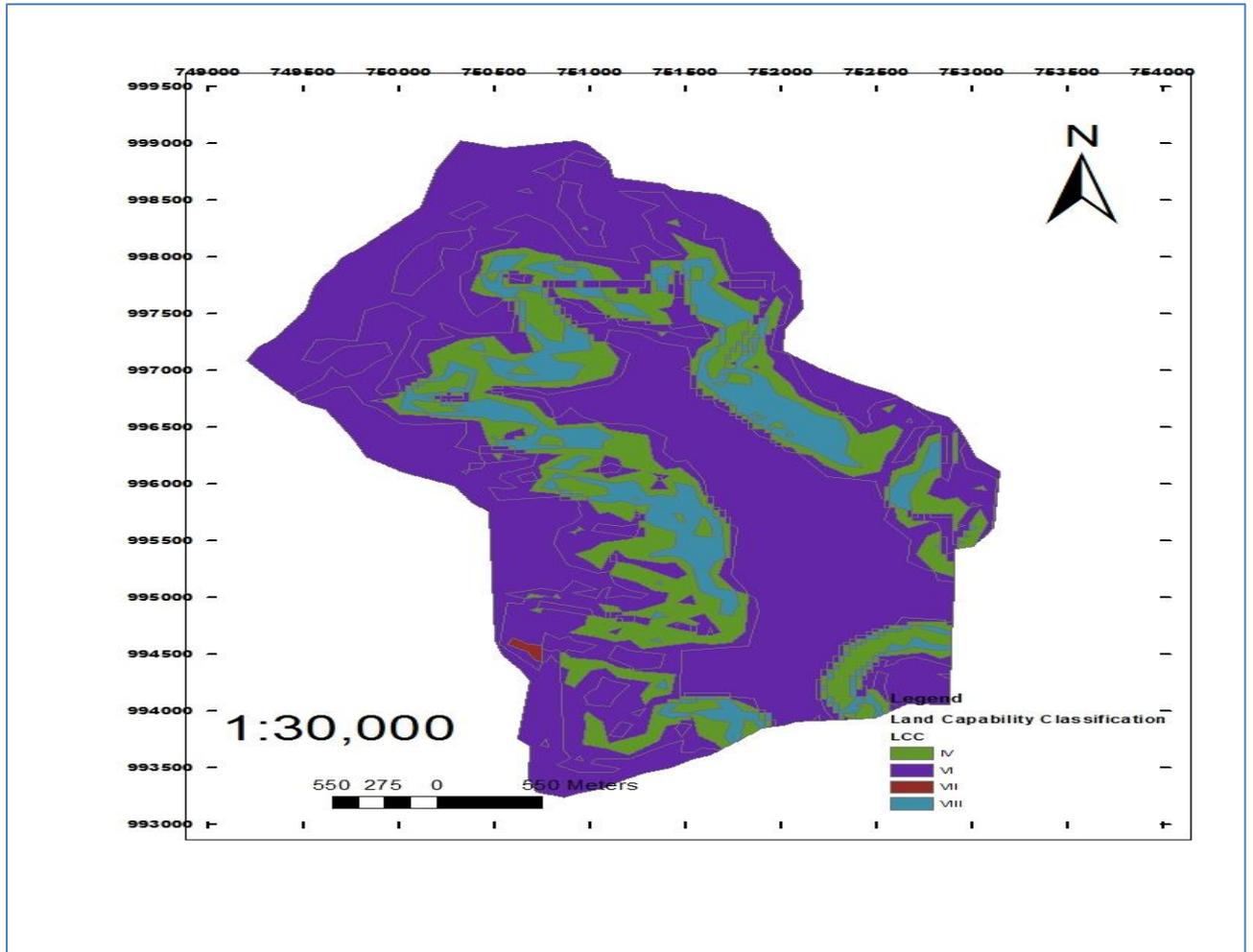


Figure 10-1: Map of land capability sub-class of the watershed

Table 10-5: Description of land capability units (LCU)

LCU	Description
IVL3E1	Land capability class IVL3E1 with slope & soil erosion limiting factor
VIL4E2	Land capability class VI with slope & soil erosion limiting factor
VIIIL5E3	Land capability class VIIILE with slope & soil erosion limiting factor
VIIIIL5E3	Land capability class VIIIILE with slope & soil erosion limiting factor

---

## 11. WATERSHED DEVELOPMENT OPPORTUNITIES

### 11.1. GENERAL

Though Fir Kebso Watershed has a number of threats and constraints, there are also ample amounts of opportunities and potentials in the areas of natural resources, work experiences, policy directions and political commitments. Some of them are summarized as below

### 11.1. OPPORTUNITIES

Some of the opportunities which can be used as a motivation for watershed development to improve the livelihood of the community in the watershed (as indicated in the discussions with the community and also the team perception are;

- Availability of abundant labor at household level to undertake agriculture (crop and animal) production activities;
- Availability of biomass particularly in the homestead to prepare compost. (According to the result obtained during discussion, Fir Kebso shortage of money to buy artificial fertilizers confronts farmers in the watershed. Cognizant of this, if farmers prepare and use compost using the available biomass; they can save money allocated to buy artificial fertilizer, as well as they can enrich soil fertility for a perceivable period.)
- Availability of manure to fertilize the land using organic fertilizer; the field survey result indicates there is cattle and goat population in the watershed and the manures gained from them can be used to fertilize the homestead farm and even the field crops.
- Prior experiences of the watershed community in managing crop and animal production; although majority of the farmers in the watershed implement conventional way of crop and animal production system, their experience and exposure in the sector can be used as springboard and will have huge contribution to improve the productivity of the sector using improved technologies
- Availability of forage to carry out animal production such as cattle and goat rearing, ox and Goat fattening
- Availability of bee forage in the homestead to run beekeeping activities

- 
- Access of the watershed to nearby wereda towns to diversify their household income by involving in off and non-farm activities
  - Access of the watershed to “Zonal” town and main road to sell their agriculture produces as well as to get access to technologies
  - Relatively sufficient land; despite the watershed located in sloppy area, if well managed by applying integrated watershed treatment and improved technologies, the land holding is enough to feed the household
  - Availability of springs and small streams in the watershed. During discussion, the survey team confirmed the availability of streams, but due to the ongoing land degradation and deforestation, the existing water sources could not discharge enough volume of water particularly in the dry season. Thus, if integrated watershed treatment implemented, the runoff water which otherwise create soil erosion infiltrate to the soil which result in increasing volume of streams and springs and even new water points may emerge.
  - Existence of Sectoral Policies and Strategies
  - indigenous knowledge of the local community on traditional agro forestry practices, SWC measures and apiculture practices;
  - The decentralization and presence of government structures up to the grassroots level, which have common interest on development of natural resources;
  - the agro-ecology of the study area is suitable to introduce multipurpose trees and shrubs for livestock feed, soil fertility maintenance and ecosystem conservation,
  - The possibility of reclaiming the degraded lands as the natural vegetation in the area have fast regenerating capacities when protected from human and livestock interferences;
  - Better forest coverer that can be enhanced through continuous awareness of the community and enrichment plantation;
  - Possibility of carrying out fattening through use of livestock feed from closure areas and consequently reducing pressure on grazing and cultivated land by practicing cut and carry system;

## 12. WATERSHED DEVELOPMENT INTERVENTIONS

### 12.1. MAIN COMPONENTS

Watershed development interventions are key to improve the livelihood of people in the watershed at development through restored and enhanced land productivity, support rehabilitation of degraded land and development of natural resources, providing opportunities for income generating and contribute to small-scale infrastructure development. This will help to intensify the land productivity with no jeopardy on existing natural resources. As well watershed development interventions could save water reservoirs such as dams, by reducing silt transporting runoff water. A multiple of development interventions are proposed for such cases, and recommendations are made based on the specific site conditions. The development interventions for Fir Kebso watershed include: soil and water conservation, a forestation and forest management, crop production intensification and diversification; livestock development; income diversification; infrastructure development; alternative rural energy technology; environmental education in primary schools; and capacity building. These measures are discussed below. *For detail, description & design of physical & biological conservation measures & structures refer to Appendix I-1 to I-11 adopted from MoARD 2005 “community based participatory watershed development guideline”.*

### 12.2. SOIL AND WATER CONSERVATION

#### 12.2.1. Physical Soil and Water Conservation Measures

Physical SWC measures are those soil and water conservation measures, which lead to change in land surface arrangement and profile. There is various physical soil and water conservation measures that can be applied on different land uses types, but those proposed for Fir Kebso watershed are soil bunds, stone bunds, cutoff drains, bench terrace and waterways.

#### 12.2.2. Biological Soil and Water Conservation Measures

Biological SWC is a conservation practice that prevents loss of soil and moisture, improve soil property and maintain/restore productivity and stability of the ecosystem through good farming system, good cover, recirculation of organic matter and nutrient and establishment of vegetative barrier. A number of biological SWC systems can be applicable for the study area solely or in

combination with physical SWC measures based on the specific conditions. The proposed interventions Nursery establishment, Reforestation, Demarcation and closure of existing natural vegetation: Grass Strips, Compost Making and Utilization.

#### *12.2.3. Agro-Forestry Development Interventions*

The recommended agro forestry practices as part of the watershed development intervention are Alley Cropping and Multi-Story Gardening specifically at homesteads.

#### *12.2.4. Gully Control and Rehabilitation*

The techniques of gully control and rehabilitation include, treating upslope lands, reclaiming the gully area, diverting runoff (partially or wholly), close off, plantation and construction of different types of check dams across gullies to hold backwater and trap sediments. The type of check dams selected to treat and rehabilitate gullies depends on the gully features (depth, width, gradient, gully formation stage, slope), availability of construction materials, and slope gradient of the gullies. To this end, live brush wood check dams, stone check dam, and gabion check dam all integrated with plantations along the side of the gullies proposed for this watershed area.

#### *12.2.5. River bank Protection*

River bank erosion was observed in the project area particularly in Fir Kebso Spring and the other streams. Moreover, in these areas cultivation is practiced close to the edges of the springs. Such cultivation practices are made without any interventions that may protect the cut and slide of riverbank. In future, if the practices are allowed to continue unabated, there would be a danger of losing many cultivated lands and the proposed reservoir may be filled with sediment and consequently its effectiveness reduced.

Therefore, the measures for protection of riverbank are recommended. The intervention involves establishment of buffer zones on the sides of the River bank and upper ponds establish plantations of economically important vegetation of various types. This zone will act as a de-silting and sediment trapping zone and dispersing the concentrated run-off before entering into the springs and reservoir so that the runoff will have non-erosive effect. In this regard, establishment of buffer zone of 5-10 meters away from the edge of the River bank by limiting cultivation and other agricultural operations beyond this zone is recommended.

The buffer zone should be established with productive grass species that could be used for livestock feeding through cut and carry method; trees that can be used as fuel wood and

construction materials and fruit trees that may be useful for generating income for communities who own the land adjoining the River bank. Thus, River bank protection measures are proposed on the right and left side of the main spring.

### **12.3. PROMOTE FRUIT PRODUCTION**

Generally, the ecological condition of the study area is quite favorable for growing tropical fruit trees. It was also observed that some farmers introduced fruit production particularly in the homestead areas. Thus, this has to be strengthened through providing the necessary financial and technical support.

### **12.4. WATER SUPPLY AND SANITATION**

As it was indicated in the problems of the watershed, water supply and sanitation is the serious problem that causes animal wastes drop out and many water born and water related diseases. Thus, it should be the first intervention in the watershed development. There are not sufficient water sources particularly in the upstream part of the watershed; hence construction of hand dug and shallow well taken as alternatives to alleviate water constraint.

### **12.5. ACCESS FOR CREDIT SERVICES**

The households in the watershed have a limited capacity to purchase farm inputs mainly fertilizer, buy improved livestock and accessing their fodder, and start any kind of business in the project area. However if there is a strong credit facility, these households will have a chance to build their financial capacity. Thus for the project to be successful, there must be a strong credit services in the watershed.

### **12.6. HOMESTEAD FARMING**

Homestead farming has significant contribution in supporting the livelihoods of the households in the watershed. Farmers are applying manure to increase the yield of homestead farming. This is a good practice and needs to be strengthened.

## 12.7. VEGETABLE PRODUCTION

Except few farmers vegetable production has not been undertaken by majority of the households in the watershed. Fir Kebso stage of irrigation water is the main reason that impedes the farmers in this particular activity. In this regard if integrated watershed development is practiced through the improvement of water resources mainly by improving the infiltration of rainwater thereby increasing the volume of water, which creates opportunity to undertake vegetable production, the sector would be significantly improved and contributed a lot for the households.

## 12.8. DIVERSIFYING ANIMAL PRODUCTION AND IMPROVE PRODUCTIVITY

As discussed with the experts the area has big potential for cattle rearing, oxen and shoat fattening, poultry production, beekeeping, etc. Despite its potentials, the community is not benefiting out of it, because they are undertaking conventional method of animal production methods. Lack of practical training on the sector and skepticism in the side of the community are among the contributing factors for unproductive animal production. To alleviate the prevailing constraints and to improve productivity the survey team suggested the following strategies.

**Farmers should be advised to practice cut-and-carry system, instead of free grazing:** As mentioned in the earlier section, the watershed is situated in a very sloppy area, therefore free grazing aggravates soil erosion and environmental degradation. To stop if not to reduce overgrazing and its negative consequences, the farmers in the watershed should be advised to use cut-and-carry system as well as should get awareness training regarding the benefits of cut-and-carry system.

**Engage farmers in oxen and goat fattening activities:** Very few farmers undertake fattening activities, in rainy season; (fattening is not done in dry season because of lack of forage to feed animals). Hence, farmers should get in depth and practical training on fattening techniques and management to run the activities year round using cut- and-carry as well as hay system.

**Involve female farmers in poultry production:** Result obtained from PRA session shown poultry production is another livelihood option mostly carried out by female farmers. In these, connection in depth and practical training needs to be provided on poultry production and management for female farmers.

**Involve farmers in Beekeeping:** Beekeeping is another livelihood opportunity that needs priority. Despite the availability of bee forage, the farmers do not undertake beekeeping

activities. The farmers do not possess the required experience, skill and knowledge to carry out beekeeping activities. Therefore, the following points should get high emphasis to earn substantial benefits from apiculture.

- In depth and practical training on apiculture should be provided to farmers
- Farmers in the watershed should get repeated advise and extension service to use manual weeding rather than using agrochemicals, since there are abundant labor at household level
- Provide improved beehives and seed money for farmers to promote the sector.

### **12.9. INTRODUCE FUEL SAVING STOVE FOR ENERGY SOURCE**

Almost all HHs in the watershed are using biomass as energy source, which triggers deforestation and exacerbates soil erosion. Therefore, to mitigate deforestation, thereby to reduce sediment generation and delivery to the proposed infrastructure, provision of fuel saving stove and solar lantern for the HHs in the watershed should get priority.

## 13. PROPOSED WATERSHED DEVELOPMENT PLAN

### 13.1. HOT SPOT AREAS IDENTIFICATION

The development option is the most important parts of the development plan for the technician and other stakeholders involving in watershed management.

We assessed the watershed characteristics and identified a hot spot areas based on the following but not limited to; Areas with land capability classes, Biophysical characteristics such as land use, farming system, topography and slope and shall include intensively cultivated land with slopes greater than 15%. Moreover, current erosion status, erosivity, drainage pattern have been investigated to include area with dendritic and dense drainage pattern, severe to very severe erosion having densely populated human and livestock number.

Approximately 27% of the area has a slope gradient less than 15%. However, very steep slopes (greater than 60%) are also present, increasing the risk of erosion in these hilly areas. The potential reading of the resulted maps showed that the most affected areas with erosion lie within the watershed where there are very steep slopes, soft soil cover, and intensive runoff. In addition, down from the uplands in Fir Kebso watershed, there are several hotspots formed due to the erosion by mass movement which due to the existence of specific soil types.

Combining potential erosion estimates with information on the type and/or intensity of land use will help to identify hotspots. Although the extent varies from place to place, that the highest erosion per hectare of land occurs in steeper slope. This is attributed to the longer slope length, and poor management practices. Comparative analysis was done to identify sensitive parameters for soil loss in the study area. As can be indicated from the map (Figure 7-1) extent of higher soil losses occurs in all parts of the study area when slope >30%. Thus, this may be a big challenge unless proper watershed management measures applied on the watershed.

### 13.2. PROPOSED WATERSHED DEVELOPMENT PLAN AND OPTIONS

Based on the general components discussion with due consideration of the biophysical and socio-economic situation of the watershed the development options are drawn and recommended. The proposed development interventions are presented in table 14-1 below. *For detail, description & design of physical & biological conservation measures & structures refer to Appendix I-1 to I-11 adopted from MoARD 2005 “community based participatory watershed development guideline”.*

**Table 13-1: Proposed Development plan and Options of Conservation Practices by land capability sub-class**

LCSC	Major limiting factors	Cultivated land	Grass land	Shrub land	Bush land
IVL	Slope (15-30%)	<ul style="list-style-type: none"> <li>Establish of perennial crops;</li> <li>Convert to grassland or forestland;</li> <li>Bench terraces for annual crops + waterways</li> </ul>	<ul style="list-style-type: none"> <li>Grassland improvement;</li> <li>Controlled grazing;</li> <li>Convert to Silvipasture + cut-off drains</li> <li>Cut and carry system</li> </ul>	<ul style="list-style-type: none"> <li>Gully erosion control</li> <li>Enrichment plantation</li> <li>demarcation and protection</li> </ul>	<ul style="list-style-type: none"> <li>Area closure + cut and carry system</li> <li>Enrich plantation of grasses and leguminous</li> <li>demarcation and protection</li> </ul>
IVLE	Slope (25-35%) and past erosion (moderate)	<ul style="list-style-type: none"> <li>Bunds</li> <li>Cut of drains + Waterways</li> <li>Alley cropping</li> <li>Bunds stabilization with grass/shrubs</li> <li>Vegetation barriers</li> <li>Selected shallow roots crops</li> <li>Contour cropping</li> </ul>	<ul style="list-style-type: none"> <li>Cut-off drain &amp; waterways</li> <li>Gully rehabilitations</li> <li>Grazing land improvement</li> <li>grazing system</li> <li>over sowing with leguminous trees and grass seeds</li> <li>zero grazing</li> </ul>	<ul style="list-style-type: none"> <li>Establish silvipasture site;</li> <li>Enriching tree species;</li> <li>Fuel wood plantation + micro basins</li> <li>demarcation and protection</li> </ul>	<ul style="list-style-type: none"> <li>Enrichment plantation</li> <li>Protection</li> <li>Forest management plan</li> </ul>
VIL	Slope (>35%)	<ul style="list-style-type: none"> <li>Bench terraces,</li> <li>grass strips on the terraces,</li> <li>Micro-basins and trenches,</li> <li>diversion ditches, and multipurpose trees plantation,</li> </ul>	<ul style="list-style-type: none"> <li>Pasture land improvement</li> <li>Controlled grazing system</li> <li>Grazing land management</li> </ul>	<ul style="list-style-type: none"> <li>Gully erosion control</li> <li>Enrichment plantation</li> <li>demarcation and protection</li> </ul>	<ul style="list-style-type: none"> <li>Enrichment plantation</li> <li>demarcation and protection</li> </ul>

LCSC	Major limiting factors	Cultivated land	Grass land	Shrub land	Bush land
VIII E	Past erosion (very severe erosion)	<ul style="list-style-type: none"> <li>• Convert to forest land</li> <li>• Catchment protection</li> <li>• Area closure</li> <li>• Cutoff drains + natural water ways</li> </ul>	<ul style="list-style-type: none"> <li>• Area closure;</li> <li>• Cut and carry;</li> <li>• Convert to forest land</li> </ul>	<ul style="list-style-type: none"> <li>• Area closure</li> <li>• Demarcation and protection</li> <li>• Encourages wild life protection</li> <li>• Moisture conservation measures</li> <li>• Gully control and reclamation</li> </ul>	<ul style="list-style-type: none"> <li>• Area closure</li> <li>• Demarcation and protection</li> <li>• Encourages wild life protection</li> <li>• Moisture conservation measures</li> <li>• Gully control and reclamation</li> </ul>

### 13.3. PROPOSED WATERSHED DEVELOPMENT MAP

Based on land capability class evaluation as above, assessment of soil erosion status, land use land cover, slope, and hot spots sites identified; development map is prepared to show priority areas that need immediate intervention. The map is presented in figure 13-1 below and the Legend in table 13-2.

In reference with watershed development map for micro-watersheds, the development intervention activities recommended to be carried out starting from upper watershed to lower parts of the watershed. *For detail, description & design of physical & biological conservation measures & structures refer to Appendix I-1 to I-10 adopted from MoARD 2005 “community based participatory watershed development guideline”.*

**Table 13-2: Legend for Fir Kebso SSIP Watershed Development Map**

Symbol	Description	Symbol	Description
WW	waterways	ZG	Zero Grazing
BGS	Bund with grass strip	IFM	integrated forest management
SSI	Soil Structure Improvement	TrC	Trench Construction
GEC	Gully Erosion Control	FWTP	Fuel wood Tree Plantation
BT	Bench Terraces	MBC	Micro-Basin Construction
AC	Area closure	SB	Soil Bund

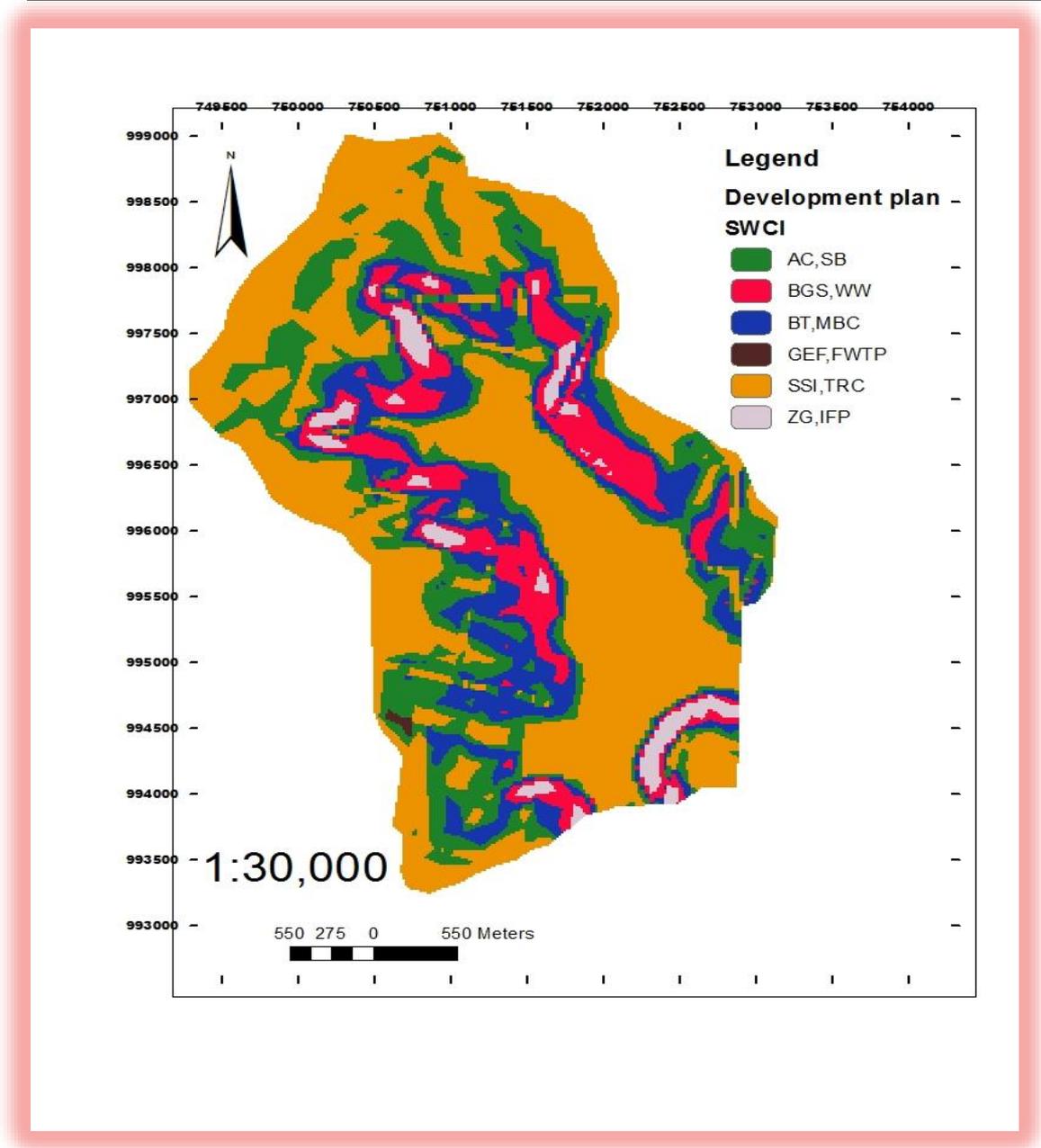


Figure 13-1: Fir Kebso SSIP Watershed Development Map

## 14. IMPLEMENTATION PLAN, COST ESTIMATE AND BENEFITS

### 14.1. IMPLEMENTATION PLANS & SCHEDULE

The proposed watershed development interventions are supposed to be implemented in phases, with some proportion of each activity in one year or throughout the life of the project. The plan as indicated below includes timeframe for the activities with sequence of tasks. The list of inputs required; strategic issues that should be considered for successful implementation and institutional arrangements are discussed separately.

The implementation of development activities is developed based on priority and prerequisites, where the planning considers the sequencing and phasing of the project, and farming calendars and livelihood opportunities of the community in the watershed. The implementation of physical and biological soil and water conservation activities follows the awareness creation and capacity building interventions, and precedes other livelihood improvement mechanisms.

The watershed development, plan and implementation period is proposed to be three years, which is subject to revision dependent on budget, current cost and labor availability, the level of community participation and the period required to ensure sustainability. The proposed activity and implementation time schedule is presented the table below:

**Table 14-1: Development Interventions Implementation plans & Schedule**

S.No	Activity by component	Unit	Total Plan	Activity plan by year		
				Year - 1	year-2	year-3
1	Soil bund	km	15	5	5	5
2	Stone faced soil bund	km	8	2.67	2.67	2.67
3	Stone bund	km	18	6	6	6
4	Bench terrace	km	10	3.33	3.33	3.33
5	Cut off drain	M <sup>3</sup>	270	90	90	90
6	Water way (stone paved)	M <sup>3</sup>	120	40.00	40.00	40.00
7	Live check dams with sisal or other trees	Number of	45000	15000	15000	15000

		seedlings				
8	Stone check dams	M <sup>3</sup>	35.25	11.75	11.75	11.75
9	Grass strips	Km	210	70	70	70
10	Gabion check dam	M <sup>3</sup>	45	15	15	15
11	Trench Construction	No	12000	4000.00	4000.00	4000.00
12	Micro- basin	No	525	175.00	175.00	175.00
13	Cook stove producer	group	4	4		
14	Compost pit digging	M <sup>3</sup>	150	50.00	50.00	50.00
15	Spring development	No	6	2	2	2
16	Area closure	Ha	60	20	20	20
17	Nursery establishment	No	1	1.00		
18	Seed collection		0	0.00	0.00	0.00
	Trees	Kg	9	3	3	3
	Legumes	kg	9	3.00	3.00	3.00
	Grass	kg	6	2	2	2
	Fruit tree seedling	No	2250	750.00	750.00	750.00
19	Spring side protection and gully vegetation	Ha	24	8.00	8.00	8.00
20	Seedling Production	No	540000	180000	180000	180000
21	Seedling Plantation	No	540000	180000	180000	180000

## 14.2. INPUTS AND COST ESTIMATES FOR THE WATERSHED DEVELOPMENT

The required items and of inputs are computed based on existing considerations. The work norms that have been developed before years are also considered partially, as many things are changed over the past decade. Detailed needs assessment could be conducted to verify the item requirements, the costs of each item, and the rates of payments per person days for labor costs.

The amount of items and activities might come up with slight changes, and the costs could be adjusted based on budget and labor availability, urgency to address the problems, and the period required to ensure sustainability.

The costs for the watershed development and management activities have been prepared based on detailed area data of land cover and slope classes obtained from the GIS. Work norms and costs as provided in the MoARD Guidelines 2005 have been used in order to calculate the cost rates. These apply to the costs for most intervention activities. Project unit costs for some activities were estimated using per kebele or woreda estimates derived from data collected by similar Project - distribution Analysis. Detail analysis performed in table 14-2 and 14-3.

The total cost required for the implementation of the development interventions in the three project implementation years and proposed materials and estimated budget are presented in table 14-3 below

**Table 14-2: Cost Estimate for development activities**

No	Type of Activities	Unit	Work norm	Total plan	Total PD	Unit cost (birr)	Total cost needed
1	Soil bund	Km	150pd/km	15	2250	50	112500
2	Stone faced soil bund	Km	250pd/km	8	2000	50	100000
3	Stone bund	Km	250pd/km	18	4500	50	225000
4	Bench terrace	Km	500pd/km	10	5000	60	300000
5	Cut off drain	M <sup>3</sup>	0.7m3/pd	270	221	50	5525
6	Water way (stone paved)	M <sup>3</sup>	1pd/0.75m <sup>3</sup>	120	160	60	9600
7	Live check dams with sisal or other trees	Number of seedlings	1pd/50 trees	45000	900	50	45000

No	Type of Activities	Unit	Work norm	Total plan	Total PD	Unit cost (birr)	Total cost needed
8	Stone check dams	M <sup>3</sup>	0.7m3/pd	35.25	25	60	1500
9	Grass strips	Km	30pd/km	210	17145	50	342900
10	Gabion check dam	M <sup>3</sup>	1pd/0.25 m <sup>3</sup>	45	180	60	10800
11	Trench Construction	No	2pd/3trenches	12000	7992	50	399600
12	Micro- basin	No	1pd/4MB	525	132	50	6600
13	Cook stove producer	Group		4	0	40000	160000
14	Compost pit digging	M <sup>3</sup>	10pd/pit	150	1500	50	75000
15	Spring development	No	1700pd/spring	6		30000	180000
16	Area closure	Ha		60	0	0	
17	Nursery establishment	No	50000birr/nursey	1		50000	50000
18	Seed collection	Kg		0			
	Trees	Kg	20pd/kg	9	180	50	9000
	Legumes	Kg	20pd/kg	9	180	50	900
	Grass	Kg	10pd/kg	6	60	50	3000
	Fruit tree seedling	Birr	30birr/seedling	2250		67500	67500
19	Spring side protection and gully vegetation	Ha	500pd/ha	24	12000	50	600000
20	Seedling Production	No	15pd/1000 seedling	540000	8100	50	405000
21	Seedling Plantation	No		540000	8100	50	405000
	Capacity Building (Farmers and experts)	Birr	LS		2times	120,000	240000
	Overhead costs (Coordinator, consumables, etc)	Birr	LS		36 months	15000	540000

No	Type of Activities	Unit	Work norm	Total plan	Total PD	Unit cost (birr)	Total cost needed
	M&E Cost (Per Diem, fuel & Oil)	Birr	LS		9 times	5000	45000
	Sub total						4,339,425

Table 14-3: Materials requirements and cost estimate

No	Item	Unit	Quantity	Unit price (birr)	Total price (Birr)
1	Digging hoe	No	200	200	40000
2	Spade	No	200	250	50000
3	Pick axe	No	150	200	30000
4	wheel barrow	No	20	1200	24000
5	Craw bar	No	40	750	30000
6	Purchase of Bee hives with accessories	No	60	4000	240000
7	Meter tape(50m)	No	5	200	1000
8	Tie-ridger	No	35	1500	52500
9	Gabion	M <sup>3</sup>	352	1000	352000
10	Tree seeds	kg	24	1000	24000
11	Seedlings /Vetiver& Fruit	No	300000	3	900000
12	Clinometers	No	3	4000	12000
13	Line level	No	4	45	180
14	GPS	No	2	5000	10000
15	Polyten tube (Ø 8mm )	qt	2	500	1000

Sub total				<b>1,766,680</b>
Grand total				<b>6,106,105</b>

**14.3. BENEFITS**

Integrated watershed management aims to improve the livelihood of community by increasing their earning capacity through offering improved facilities required for optimum production. It also helps to design a land use system that utilizes the natural resources of the area to the maximum sustained benefit of the inhabitants and to improve living standard of the community. Improved watershed management offers many potential benefits for the farmer, the local community, the larger cross section of society.

***For the farmers:***

- Increased production and higher profits
- Improved water availability for crop production
- Improved soil quality and better drainage
- Improved livelihoods

***For the local community:***

- Lowers the land-development costs
- Reduced flooding and water logging
- Reduced soil erosion and land degradation
- Increased productivity of agricultural crops and other biomass
- Improved livelihood options
- A more dependable, clean water supply for domestic and industrial use

***For the larger cross section of society:***

- Less danger from floods to downstream farmlands and infrastructure
- Reduced sedimentation of costly irrigation projects
- Better conservation of natural resources

Increased crop production will primarily derive from improved productivity. There will be a small increase in the cropping intensity, due to the expansion of irrigated land. Under the full soil and water conservation program, it is anticipated that the area of cultivated land will remain unchanged.

Future cropping patterns will still be dominated by cereal production. However, significant increases in the yields of these staple foods will be critical to meeting household food requirements as well as growing market demand. Furthermore, the project will promote the production of fruit and vegetables. An expansion in the area of pulses will also play an important role in enhancing soil fertility. Because of project interventions, the annual production of cereal, pulse and oilseed crops is expected to rise. In addition, there will also be substantial increases in the production of potatoes, vegetables and fruit crops.

Livestock productivity is expected to significantly increase with the adoption of improved husbandry practices, particularly with respect to nutrition and animal health. The economic benefits of the forestry component mainly comprise the additional value of fuel wood and construction poles resulting from the agro-forestry activities.

With respect to public services, the benefits of improved access and communications, as well as water supply/sanitation, health and education facilities have not been quantified. It is, however, implicit in the analysis that these improvements to rural infrastructure are critical to achieving the direct economic benefits generated by the sustainable development of crop, livestock and forestry production within the project area. For example, improved access and communications will be essential for the marketing of the additional agricultural surpluses, while improved water supply and sanitation facilities will significantly enhance human health and labor availability.

#### **14.4. IMPLEMENTATION STRATEGIES**

**Development Should Start at the Top of the Watershed:** The implementation of the proposed development interventions should start at the most top part of the watershed. The entire Fir Kebso watershed is divided in to two micro-watersheds based on the hydrologic unit principle. The protection of the upper part of the watershed should be the first priority. In all the seven micro-watersheds, implementation shall start at the top of the watersheds. Otherwise, the runoff coming from the upper parts will damage the conservation structures at the middle or down of the watersheds and will extremely aggravate soil erosion.

**Multidisciplinary Approach has to be real:** The development of watersheds should follow vertical and horizontal management aspects. Since watershed management involves decision-making about use of resources for many purposes, a multi-disciplinary approach is essential. The development options have to be decided with real participation of all stakeholders. The issue should be not only finding-solutions, but also negotiating solutions. Specific development options have to be negotiated among all stakeholders.

**Climate Change concepts shall be included:** Watershed development addresses almost all elements of a given ecosystem and physical, socio-economic and cultural and institutional components. As within a watershed unit climate change affects the different components/resources of the watershed unit at different degrees and levels. Data and information on climate change, and particularly on adaptation, are sparse and sometimes difficult to obtain. The greatest challenges in coping with the impacts of climate change are therefore access to data, state of the art science, policies, as well as tools and funding opportunities that are specific to the area. Therefore, the wereda has to work in the inclusion of climate change in the development interventions. Some aspects, in the Fir Kebso watershed, treatment will be included, but there is the need to consider the issues seriously and include new interventions, which could mitigate climate change impacts.

**Payment for Ecosystem Services (PES) shall be adopted:** Payment for ecosystem services (PES) is being considered as one of the mechanisms that should allow societies to pay for the maintenance of these services from the ecosystem. Ecosystem services are receiving increased attention in the context of human development. The PES schemes are considered as potentially useful mechanisms to compensate those who maintain the flow of ecosystem services. In here, it is recommended that PES systems be adopted in the Fir Kebso watershed development processes at least at promotion level.

**Buffer Zone shall be established and protected along the spring and the streams:** The purpose of construction of buffer zones along the main spring and other water bodies is to provide a filter for runoff, protection of over flooding, protect the structures from siltation and pollution, and provide necessary shade in order to protect streams from extreme temperature fluctuations. This is possible through leaving adjoining undisturbed land as long as possible to serve as natural buffer zones and building vegetated strip of land bordering the water in the water bodies. In the case of Fir Kebso watershed, it is recommended that a buffer zone be established along the upper and the streams in the watershed

**Researching and documentation of best practices should be done:** To sustain and restore watershed functions and develop, through the understanding of the complexity of the system there is the critical need to make researches on the different aspect of the specific watershed. In the implementation of Fir Kebso watershed, there is a recommendation that a study be conducted on identifying researchable areas, of the watershed development elements.

**Village Economic and Social Association (VESA) techniques shall be introduced:** VESA is a social and economic association can be formed by homogenizes village community to solve their social and economic problems emerging at local level. A single VESA comprise 20\_25 village people. Each VESA are expected to develop their respective bylaws and managed by it. One VESA have a chairman, secretary and treasurer all have its own duties and responsibilities as well as authorities. All VESA members will have monthly saving and the monthly saving amount is determined by the VESA members through discussion and consensus and each member has the right to borrow based on the amount they save and the guideline stipulated in their bylaws. VESA members would arrange periodic meetings mostly on monthly basis to discuss and solve problems.

## 15. MONITORING AND EVALUATION

In almost all instances, project implementation, monitoring and evaluation are considered as best strategies in making sure that implementation of activities are checked and sustainability of development achievements is confirmed. The objective is to check that planned interventions are implemented as per the timeframe and planned resources, and to identify on whether all actors are properly participating. With this intention, the implementation of development interventions of the Fir Kebso watershed needs to be monitored day to day and evaluated periodically or at the end of the three years. Through the evaluation of the project interventions, best practices could be documented and up-scaled in other similar areas.

The watershed management activities need to be periodically reviewed and compare the results with the interim milestones prepared, provide feedback to stakeholders, and determine whether it is necessary to make corrections. Regular supervision, as part of a monitoring and evaluation exercise, should be made at all levels of implementing agencies of watershed development program.



Figure 15-1: The need for monitoring and evaluation

## 16. CONCLUSION AND RECOMMENDATION

This study has considered all the biophysical and socioeconomic features of the watershed relevant to watershed management study; based on the current study the following conclusions can be drawn:

- The result of the study indicated that the watershed is prone to intricate problems related to soil erosion and land degradation, deforestation, decline of land productivity and livestock feed;
- The study indicated that most areas of the land is used for crop production beyond its capability, perhaps could be used for forest development, that is one of the major cause of prevailing soil erosion and land degradation;
- Based on this study it has been recognized that the watershed has none to high annual soil loss potential to downstream and lower lying lands;
- The study indicated that soil erosion is common in all land use types regardless of slope, including flat to gentle sloping land depending on the land use activity applied on it;
- In the study area, generally forest cover in the form of bush land and shrub land were found to be better compared to other similar semi-arid lands of the country;
- Although the study area is experienced with some forms of erosion, this could be a big challenge to the feasibility of the proposed project as it could be mitigated through proper watershed management interventions;
- This study can help concerned organization in order to make informed decisions about which type and where to initiate watershed management for sustaining the soil and water resources.
- The scale of the study is at feasibility level, therefore; detail watershed management plan need to be prepared at manageable size of micro-watershed, levels and immediate action is required to be taken with high emphasis to areas showing higher erosion rate to control the existing accelerated erosion in the watershed and thereby reducing sediment load on the downstream areas;

- It is recommended that notable action has to be taken to all part of the watershed based on the land capability unit of the land to control soil erosion in the watershed and thereby to minimize sediment inflow to the proposed weir site areas;
- The study observed that the current forest development program in the watershed is virtually low. Thus, it is suggested that forestry development and integration of agro-forestry system shall get due attention in the study area to sustain the environment and improve the availability of various wood products for the rural community;
- Lastly, it suggested that the watershed management effort need be based on integrated and watershed logic approach with respect to micro watershed levels, instead of piecemeal approach to guarantee sustainable development within the watershed and downstream areas

## REFERENCES

1. Admasu Amare, 2005. Study of Sediment Yield from the Watershed of Angered Reservoir: MSc thesis Alemya University
2. Barber, R (1984). An Assessment of the Dominant Soil Degradation Processes, Ethiopian Highlands Reclamation Study, LURD, MoA, Addis Ababa
3. ERA (2002). Drainage design manual for Ethiopian condition.
4. EROSION AND SEDIMENT CONTROL AT CONSTRUCTION SITES GUIDELINES, 2011. City of Moncton, Engineering and Environmental Services. <http://www.gov.ns.ca/nse/surface.water/docs/ErosionSedimentControlHandbook.Construction.pdf>
5. Escobedo, J.U. (1988). Land classification for Use in soil Conservation, Community forests and soil conservation Department, MoA, Assistance to Soil and Water Conservation Programme phase II, Addis Ababa, Ethiopia.
6. FAO. 1990. Watershed management field manual, conservations Guide 13/6, Rome.
7. FDRE, MoWR/NMA2007. Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia, Addis Ababa, Ethiopia.
8. Federal Democratic Republic of Ethiopia (2011) Ethiopia's Climate Resilient Green Economy. Green economy strategy. Addis Ababa: Federal Democratic Republic of Ethiopia.
9. Federal Democratic Republic of Ethiopia – MoARD (2002). Food Security Strategy
10. Federal Democratic Republic of Ethiopia (1997b). Environmental Policy EPA, MoEDC
11. Hurni, H., 1985. Erosion-productivity-Conservation system in Ethiopia. IV International conference on soil conservation, Maracay, Venezuela.
12. Hurni H, 1988. Degradation and conservation of resources in Ethiopian highlands mountain research and development.
13. James MacLellan, P.E., CPESC, 2005 (2<sup>nd</sup> ed.). Field Manual for Erosion and Sediment Control on Construction Sites in Mississippi; Mississippi Department of Environmental Quality, Mississippi Department Of Environmental Quality,
14. Juliette Kaltenrieder, 2007. Adaptation and Validation of the Universal Soil Loss Equation (USLE) for the Ethiopian-Eritrean Highlands, Centre for Development and Environment Geography Institute

15. Lakew Desta, Carucci, V., Asrat Wendem-Ageñehu and Yitayew Abebe (eds). 2005 (Part 1 & Part 2). Community Based Participatory Watershed Development: A Guideline. Ministry of Agriculture and Rural Development, Addis Ababa, Ethiopia.
16. Liniger, H.P., R.MekdaschiStuder, C.Hauert and M. Gurtner, 2011. Sustainable Land Management in Practice – guideline and Best Practices for Sub-Saharan Africa. TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nation (FAO).
17. NCSE (1989). National Conservation Strategy of Ethiopia, National Conservation Strategy Secretariat
18. Rose, C.W. 1994. Research on soil Erosion Processes and A basis for soil conservation practices.
19. Soil Conservation Service (SCS) Technical Release No. 55 (2<sup>nd</sup> Edition).
20. Tantigegn Kebede, 2008. SOME TECHNICAL HANDOUTS FOR WATERSHED DEVELOPMENT PLANNING And SOIL AND WATER CONSERVATION, Field Manual, SWHISA, Bahr Dar, Ethiopia
21. Wischmeier WH and Smith DD, 1978. Predicting Rainfall Erosion Losses - A Guide conservation. US Department of Agriculture: Washington, DC.
22. Wright. C (1984). An Assessment of the Causes, Severity, Extent and Probable Consequences of Degradation in the Ethiopian Highlands, EHRS, Addis Ababa

# APPENDICES

## APPENDIX: Design specification and layout of some selected structural measures

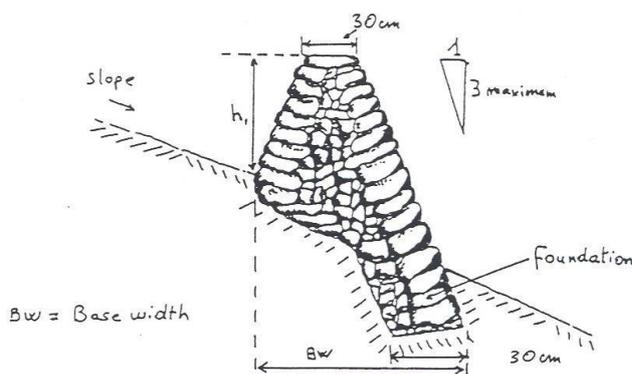
### Appendix 1- 1: Stone bund

**General description:** Stone bunds are bunds made of locally available stones or boulders. They are semi-permeable structures unless sealed with soil in their upper side. Stone bunds increase the moisture retention capacity of the soil profile and water availability to plants, and increase the efficiency of fertilizer applications. The stone bund reduces and stops the velocity of runoff and consequently reduces soil erosion and the steady decline in fertility and crop yields. Compared to soil bunds and FJs stone bunds take less space from farmlands, more durable and stable (See Figure below). This is due to that bunds with stones can be kept vertical. The need for channel is less required since the stone is impervious and excess water can make its way through. However, for dry areas need to incorporate the ditch above the bund with adequate berm. Stone bunds are entry points for application of organic residues or compost, especially in the first 2-3 meters behind the bund where soil is deeper.

#### Technical design steps/requirements

Height: 60 to 100cm (lower side). Total base width: (height/2) + (0.3-0.5 m). Top width: 30-40cm. Foundation: 0.3m width x 0.3m depth. Grade of stone face downside: 1 horizontal: 3 vertical. Grade of stone face upper side: 1 horizontal: 4 vertical. Grade of soil bank (seal) on upper side: 1 horizontal: 1.5-2 vertical. Bunds need to be spaced staggered for animals to cross. Max bund length 60-80 meters. See Figures below and at the back.

$$BW = \text{Base width} = \frac{h}{2} + 30-50\text{cm (minimum)}$$



#### Layout and construction procedures

- |   |  |
|---|--|
| <ul style="list-style-type: none"> <li>• Work out the gradient of the slope using line level;</li> <li>• Decide the spacing of the stone bunds based on the slope;</li> <li>• Excavate the foundation, place and build stone walls (larger stone for foundation);</li> <li>• Continue to build the wall with stones until you reach the desired height;</li> <li>• Fill voids between walls with smaller stones;</li> </ul> | <ul style="list-style-type: none"> <li>• Sealing of the upper side with soil as required;</li> <li>• Reinforcement of depression points;</li> <li>• Move down to the next bund and repeat the steps;</li> <li>• Repeat the same in the next bund;</li> <li>• Stabilization and application of compost;</li> <li>• Plant the bunds with grasses, fodder legumes and tree to stabilize and make it productive.</li> <li>• See Figures above and at the back.</li> <li>• As much as possible avoid round stones;</li> </ul> |
|---|--|

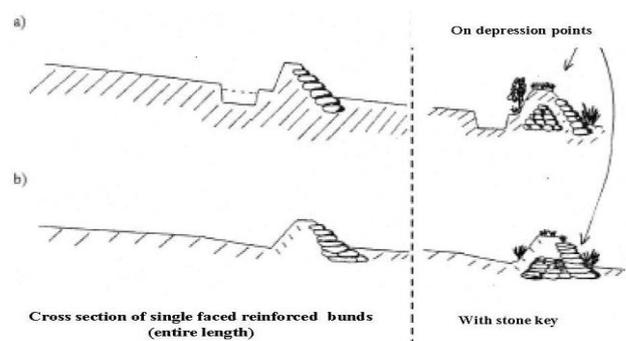
**Appendix 1- 2: Stone Faced Soil Bunds**

**General description:** Stone faced soil bunds are where one or both sides of the embankment are reinforced with a stonewall or riser. In some instances, the reinforcement may take place only along the depression points to compensate for layout problems and to protect the entire length of the bund. Strengthening of soil bunds with stones throughout their entire length is recommended wherever farmers tend to increase the spacing between structures and stones are available. Stone-faced soil bunds can be constructed in all types of soils, excluding sandy soils. For soil depth and texture same as for soil bunds. Stones should be available from the field itself or from adjacent areas. Spacing may be slightly wider than for soil bunds, particularly up to 10% on the spacing of soil bund. The dimensions of the stone faced soil bunds are identical to the ones already explained in previous section. The difference is on the stone walls placed on one or both sides of the soil bund (See Figures). Therefore, the bund is larger and stronger. In terms of layout, bunds should be level and wing up laterally in order to evacuate excess water. As mentioned for the layout of soil bunds, farmers may want to cross small depression points straight instead of curving up and down hill continuously. In this case, the entire bund should be reinforced on both sides, including a stone key.

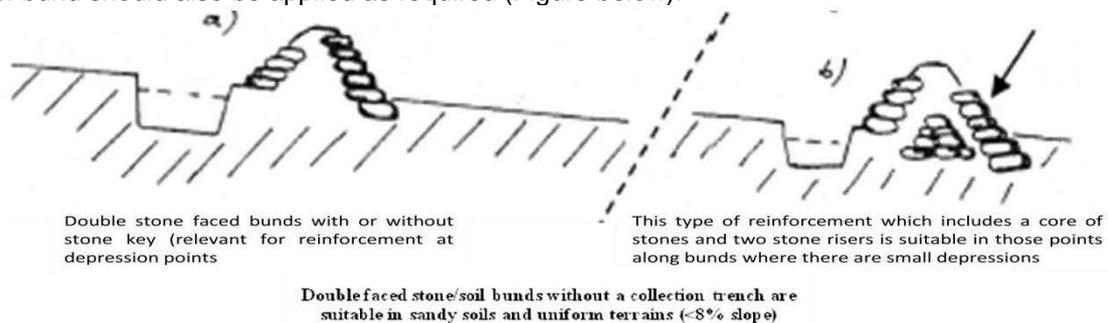
**Technical design steps/requirements**

Height: 60 to 100cm (lower side). Total base width: (height/2) + (0.3-0.5 m). Top width: 30-40cm. Foundation: 0.3m width x 0.3m depth. Grade of stone face downside: 1 horizontal: 3 vertical. Grade of stone face upper side: 1 horizontal: 4 vertical. Grade of soil bank (seal) on upper side: 1 horizontal: 1.5-2 vertical. Bunds need to be spaced staggered for animals to cross. Max bund length 60-80 meters. See Figures below and at the back. The design of these bunds is explained in the Figures below.

Types of stone-reinforced soil bunds: a) *Single faced protection wall+/- collection trench:* Stones are placed on the downstream side, well inclined to offer maximum resistance (1:2 – 1:3 vert.). A collection trench is dug on the upper streamside of the bund (see Figures a) and b) Right - show stone-faced soil bunds (single faced). They are provided with spillways if necessary (spacing, type of soils and type of crops). Stone keys are also applied in depression points if any.



**Double faced stone/soil bunds +/- collection trench:** Both sides are reinforced with stones. This type of bund is rather resistant against excess runoff. Stone keys along depression points within the earth en part of bund should also be applied as required (Figure below).



**c) Double faced stone/soil bunds without collection trench:** Are suitable for gentle and uniform slopes (<8%). The soil embankment is obtained by scratching a wider and shallow layer of top soil. Small ties can be placed at intervals along the upper side of the bund).



Double faced stone/soil bund without collection trench

**d) “Corner” or lateral stone/soil bunds:** This type of corner or lateral bunds differs from those for soil bunds because they are stone faced on both sides and through their entire length (See Figure below). In some instances, if the bend is on one side only these bunds are also called “Walking Stick bunds”. They are used for moisture retention and are suitable for lateral field boundaries with gentle slopes (<5%) where farmers want to extend their bunds w/o following a precise contour line. The bunds should then be raised at those corners and strongly reinforced on both sides with stones. The tips of the bunds winging upwards, whilst remaining level, are of decreasing height towards the slope. They may also evacuate excess water through their tips if their top level decreases inwards.



Laterally bending bund

**Layout and construction procedures**

- Some suggested standards are as follows:
- Grade of lower stone face: 1 horiz. To 3 vertical;
- Grade of upper stone face: based on soil embankment grade;
- Grade of soil: 1 horiz. to 1.5 vertical on stable soils and 1 horiz. to 2 vertical on unstable soil;
- Lower stone face riser foundation: 0.3 depth x 0.2 – 0.3 width;
- Upper stone face riser foundation: 0.2 x 0.2 m;
- Stone size: 20 cm x 20 cm stones (small and round shape stones not suitable);

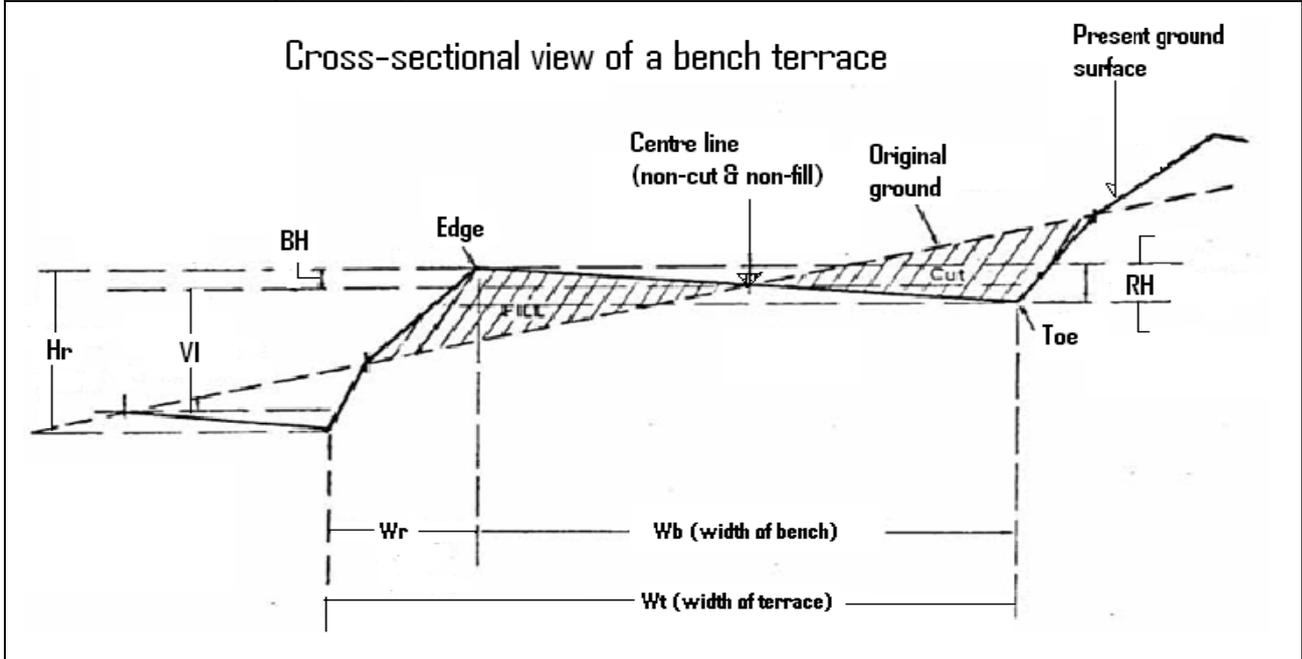
- Top width: 0.4 - 0.5 m;
  - Height: min 0.7 and max 1 m (lower stone face); and Ties: required every 3- 6 m
- Stone faced bunds can be constructed by digging a foundation for stone blanket. Large stones are then placed in the ditch with the right inclination. Soil then dug from a trench on the upper side and, together with smaller stones is recommended. The rest technical specifications are identical to soil bund. Provision of spillways can be placed at the end, in the middle or in whatever convenient position with its apron at the outlet.

**Appendix 1- 3: Bench Terraces**

**General description:** Bench terraces are a series of level or virtually level strips running across the slope (along the contour lines) at vertical intervals, supported by steep banks or risers. They are suitable for slopy land farms with a considerable depth of soil, and for farms which are being intensively cultivated. In the literature bench terraces are sometimes differentiated from the common and conventional SWC measures in the way i.e. time taken for their make-up. Excavated bench terraces carried out at one go through cut and fill process are known as “Radical terraces” while the gradually developed terraces through the action of erosion, cultivation operation, and deposition are known as “Progressive terraces”. The purpose of bench terracing are: a) To reduce soil erosion and instead conserve it (i.e. retain sediment); b) To contribute for maximum moisture retention in the soil – with this respect bench terraces are more relevant for moisture stress areas; c) To ease the cultivation operation; and d) To achieve uniform plant growth over the width of the bench. .

**Technical design steps/requirements**

When planning, designing, constructing and managing bench terraces some common terms/terminologies that one needs to be familiarize with are given below: Soil depth; Width of terrace; Terrace riser; Lip; Toe; Drain; Forward sloping; Outward sloping; Backward sloping; Reverse sloping; Inward sloping; Double sloping; Level vs graded terraces; Individual terrace; Continuous terraces; Discontinuous terraces; Transitional terraces; Vertical interval; Height of riser; Riser slope; Cut-depth; Fill height; Dike height; Dike cross-section; Horizontal interval; Width of riser; Width of bench; Cut section; Fill section; Linear length of terraces; Net area of bench terrace; Construction sequence; Progressive versus radical terraces; Developed versus constructed terraces; Excavated versus developed terraces; Layout and surveying procedures; Center-line (non-cut or non-fill); Slope in degree; Slope in percentage; Equipment for surveying; Tools for construction; Use of tractors and bulldozers; Waterways; Manuring; Cost of bench terracing; Top soil treatment; Top soil preservation; Irrigated bench terraces; Rain-fed (Upland bench terraces); Bulk density of the soil; Angle of repose; Percentage of bench; Cross-sectional area of the bench terrace; Reverse height; Outward height; Wider terrace versus narrow terrace; Cultivation of high value crops; etc. For designing bench terraces, consultation of proper manual on the technique is required; however, the following quick steps can be followed.



$$D = \frac{Wb}{2} \tan \phi \text{ (for level terraces)}$$

$$D = \frac{Wb}{2} \tan \phi + \frac{RH}{2} \text{ (for reverse - sloped terraces)}$$

$$D = \frac{Wb}{2} \tan \phi - \frac{OH}{2} \text{ (for outward - sloped terraces)}$$

Where; D: depth of cut in m; Wb: width of bench in m;  $\phi$ : tangent of the slope angle.  
 RH : reverse height; OH: Outward height

(viii) **Net Area:** This is the area in benches or flat strips which is used for cultivation. The net area can be calculated by using the following formula:  
 Where A is net area of benches per ha in  $m^2$ ; Wt: width of terraces (the sum of the width of the bench and the width of the riser), in m; Wb: width of the bench, in m; When calculating the net area of level terraces, the dyke width should be subtracted.

(ix) **Cross section:** The cross-section can be computed by the following formula:  

$$C_A = \frac{Wb \cdot Hr}{8}$$
 Where,  $C_A$ : Cross-sectional area of the cut triangle, in  $m^2$ ; Wb: Width of bench, in m; Hr: Height of riser, in m

The linear length of terraces per hectare can be calculated by the following equation:  $L = \frac{10,000}{Wt}$

The linear length of terraces per acre can be calculated by the following equation:  $L = \frac{43,560}{Wt}$

L: Linear length of terraces in one hectare, in m; Wt: Width of terrace, in m (where  $Wt = Wb + Wr$ ).

The volume (V) can be calculated by multiplying the linear length (L) by the cross-sectional area ( $C_A$ ):  $V = L * C_A$ ; When calculating the volume to be cut and filled it should be noted that only one cross-section is used. This is because the same cross-section is moving down slope to form a terrace.

For level terraces, the following formulas should be used for computing cross-sectional area:  

$$C_A = \frac{Wb \cdot VI}{8} + DC$$
 Where, C : cross-section, in square m; Wb : width of bench, in m; VI : vertical interval, in m; DC: Dyke cross-section, in square m (or  $m^2$ )

For outward-sloped terrace a modification of the riser height (Hr) is required for calculating cross-section and volume as follows:  
 $Hr = VI - OH$ ; Hr: Height of riser; VI: Vertical interval; OH: Outward height (equals width of bench multiplied by 0.03)

**Layout and construction procedures**

Layout of terraces should include an examination of the site's physical conditions such as slope, soil depth, texture, erosion, presence of rocks, wetness, vegetation cover and present land use. This entails clearing the area, preparing survey equipment, stakes, color ribbons or markers, and deciding on survey methods and sequences. Equipment: the equipment usually consists of: dumpy level, abney level or A-level or A-frame; measuring tape and rod; and soil auger. For level terraces: use contouring or levelling techniques. For upland bench terraces: use graded-contouring techniques. Techniques of layout: i) Setting an up-and-down base-line at the site along a representative slope; ii) Use of center-line method i.e. a quick calculation of the VI; iii) Use a level to determine and stake the VI of the terraces along the base line. The stakes should be streamlined if there are sharp turns and narrow bottlenecks as these will interfere with future operations. Streamlining the stakes entails extra cuts or fills but is worthwhile in the long run.

**Marking stakes:** Each contour line of stakes should be marked with a different color ribbon or paint in order to avoid confusion during construction, (e.g. center lines in red, and side lines in yellow or green, etc.).

**Construction methods:** The cut and fill of the terraces should be done gradually and at an equal pace so that there is neither an excess nor a lack of soil. This principle applies regardless of what kinds of tools are used for the operation.

The terrace must be built when the soil is neither too dry nor too wet. Start building the terrace from the top of a hill and proceed down slope

Tie cord or rope around the stakes to mark each constructed terrace in sequence. The initial cut must be made immediately below the top stakes while the fill work should be started against the bottom stakes. This is done in order to ensure that the correct grade is attained without overcutting. Sometimes, rocks or clods of earth can be placed along the bottom line of the stakes to serve as a foundation before filling. During the filling operation, the soil should be compacted firmly by a beater every 15 cm layer. If the layer of soil fill is thick, the compacting process becomes difficult. Terraces across existing depression areas should be built particularly strong. The edge of a terrace should be built a little higher than planned because of settling. The rate of settling may be as high as 10% of the depth of the fill. Both the reverse and horizontal grades should be checked by a level during construction work and corrections made promptly. The slope of the riser should be shaped to 0.75:1. Waterway shaping should be commenced only after the terraces are cut. Make sure all the terrace outlets are higher than the waterway bottom.

**Topsoil treatment or preservation:** BTs usually expose the infertile subsoil and this can result in lower production unless some prevention or improvement measures are undertaken. **Two alternative methods follow:** i) The terraces should be built from the bottom of the slope upwards. After the bottom terrace is roughly cut, the topsoil from the slope above is then pulled down to the lower bench and spread on its surface. Repeat this procedure for the next terrace up the slope and proceed uphill in this way until the top terrace is built. Of course, the top terrace will not have topsoil unless it is obtained from another place. ii) The second method is to push the topsoil off horizontally to-the next section before cutting the terrace. The topsoil should be pushed back when the bench is completed. For hand-made terraces, the topsoil can be piled along the center line provided

that the bench is wide enough.

**Appendix 1- 4: Cutoff drain**

**General description:** A cutoff drain/diversion ditch is a graded channel constructed to intercept and divert the surface runoff from higher ground/slopes and protect downstream cultivated land, village, agricultural infrastructures like irrigation headwork and active gully heads. Cutoff drain safely diverts the runoff to a natural or artificial waterway, Spring, or run on areas.

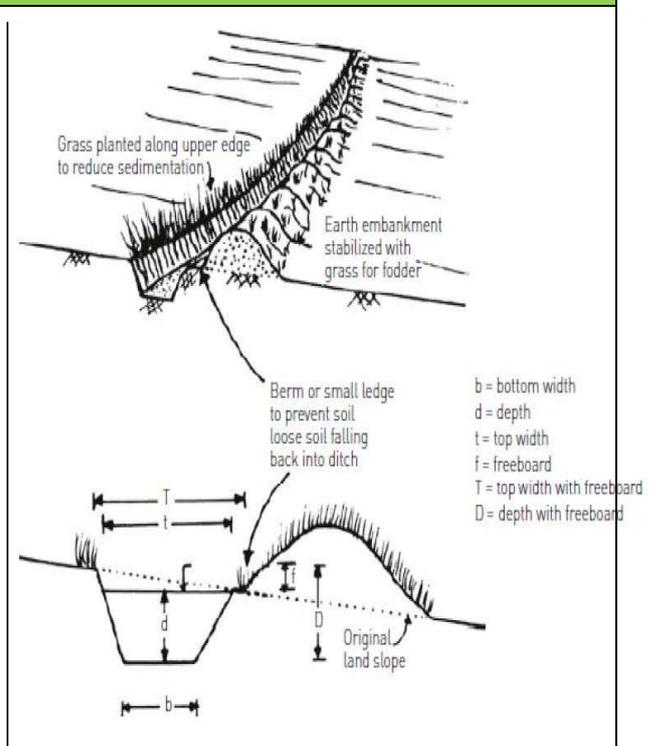
In the dry lands, cutoff drains may be used mainly for the following purpose:

- Protect cultivated land from runoff generated from sparse forest land or degraded grazing land, steep slopes, etc.
- Divert additional water to cultivate plots
- Divert additional water to sediment storage dams and cropped areas
- Divert additional water into reservoirs for irrigation and/or domestic uses (including water supply for livestock).

**Technical design steps/requirements**

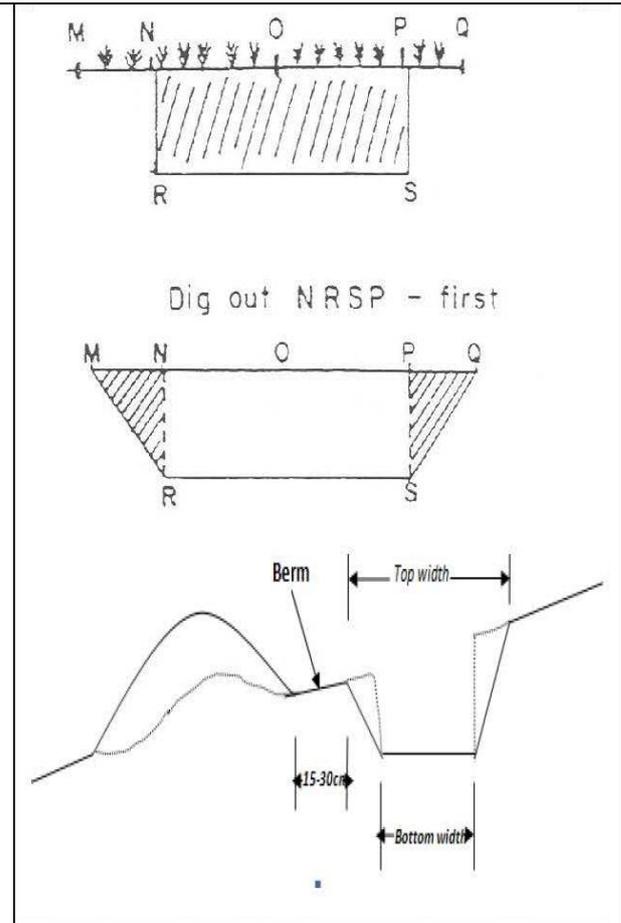
The design of any structure to retain or discharge runoff should be based on a reasonable estimate of the volume of runoff (m<sup>3</sup>) to be retained or on the peak rate of runoff (m<sup>3</sup>/s) to be discharged respectively. Usually the design of graded structures like cutoff drains will be based on the heaviest storm that can be expected in a given period (10 years). Accordingly, in order to prepare a feasible design of a cutoff drain the following steps are required:

- Estimate the runoff rate of the upper catchment using Rational or Cooks methods as described in the annex part of this manual,
- Select maximum allowable velocities which can fit to the soil and cover condition of the channel
- Decide the channel gradient which will not bring scouring and allow siltation
- Determine permissible depth of flow, its bottom and top widths
- Check if the dimensions given can accommodate the discharge which is coming into the channel.



**Layout and construction procedures**

- As per the selected channel gradient, lay out graded line.
- While making graded line, put pegs at interval of 10 m along the central line of the drainage channel (through 'o' in the graphics)
- Depending on the width of the channel, **two rows of pegs** should be erected following the graded contour along 'MN' and 'PQ'
- The distance between NO and OP is equal and it gives the bottom width of the channel
- The distance between MN and PQ could also be equal if the same side slope is chosen for both. But if the side slopes are not the same then they are not equal.
- First start digging of a rectangular section (NRSP) whose top width is equal to the bottom width of the channel to the level of the designed depth
- The excavated soil should be through downhill and form a well compacted embankment by leaving 15-30 cm berm space to avoid the moving back of the soil.
- Depending on the side slopes used, shape the sidewall of the channel. When the sidewalls are shaped in a straight inclined line then you have a trapezoidal cross section shown as MRSQ
- After completing the digging of the channel, depth, width and the gradient should be rechecked and corrected if any problem is observed.
- Reinforce properly around the outlet. A good grass cover should be established on the embankment to stabilize it.

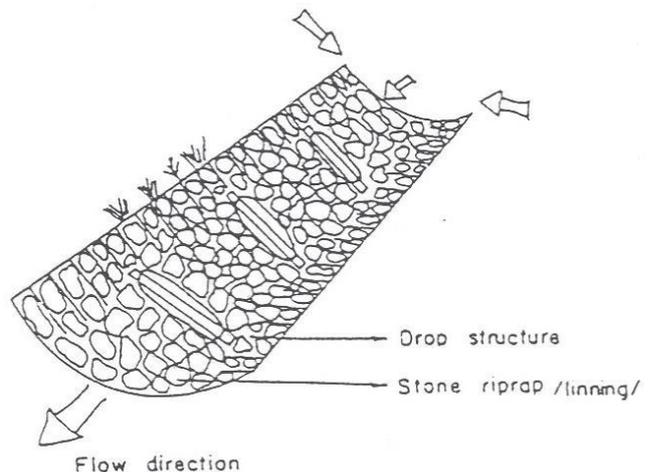


**Appendix 1- 5: water way**

**General description:** A waterway is a natural or artificial drainage channel along the steepest slope or in the valley used to discharge runoff. An artificial waterway is a drainage structure that can receive and dispose excess runoff from cutoff drains and graded terraces to the natural watercourse, percolation & water harvesting structures. Waterways are needed to conduct runoff safely from hill slopes to valley bottoms where it can join a stream or Spring. Where there is a natural depression or small valley that is well stabilized with vegetation this may be adequate to take the discharge from diversion ditches or graded terraces, but where there is no such natural waterway, an artificial waterway (drainage way) must be installed. In areas where stone is available the waterways will be paved to protect it from scouring. Whereas, a vegetative waterway can be constructed in areas without stones.

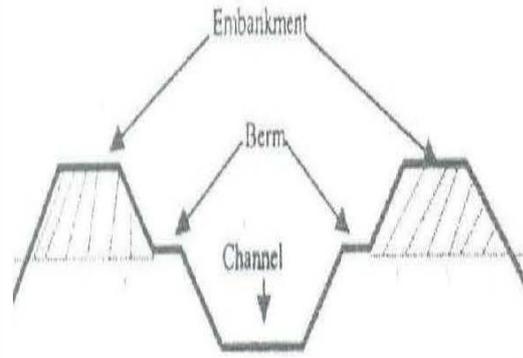
**Technical design steps/requirements**

- There are many factors to be considered in designing vegetative or paved waterways:
- **Slope:** The slope of a waterway is normally the slope of the land at right angles to the contour. Vegetative waterways are recommended for slopes < 10% and stone paved waterways can be implemented up to 20-25%.
- **Shape:** Choose parabolic cross section for types of waterways as this tends to resemble natural waterway.
- **Size:** The waterway must have sufficient width and depth to accommodate the expected runoff volume. Several small waterways are preferred than one very large one, and the waterways should be close enough to each other to avoid the terraces being excessively long.
- **Freeboard:** Waterway designs are normally based on the peak run-off expected in a ten-year return period, but to provide for exceptional conditions, a safety margin (freeboard) is added by increasing the design depth by 25% for vegetative waterways and 10% for stone-paved waterways.
- **Channel roughness:** The rougher the surface over which water flows, the greater the resistance to flow. The velocity of water in a channel can be reduced by making it wider and shallower (i.e. lowering the hydraulic radius) or by making the surface rougher. One of the ways of making the surface rougher is by planting grasses. A tall grass will provide more resistance to flow than a Fir Kebso one, although the resistance will be lowered if it is pushed over and flattened during heavy run-off. A rough stone surface will provide more resistance than a smooth concrete surface.



**Layout and construction procedures**

The preliminary position of a waterway should be determined from a reconnaissance field survey. Where possible, the waterway should be located in a natural depression or drainage way. After the waterway has been staked out, construction can start from the lower end by excavating soil from the center and throwing it to each side to form the banks. As soon as digging is complete, the waterway should be lined by planting a suitable spreading grass, or with stone or a combination of grass and stone. The process of excavation may expose less fertile sub-soil and, if so, it is advisable to use manure and mulch to ensure quick establishment of the grass.



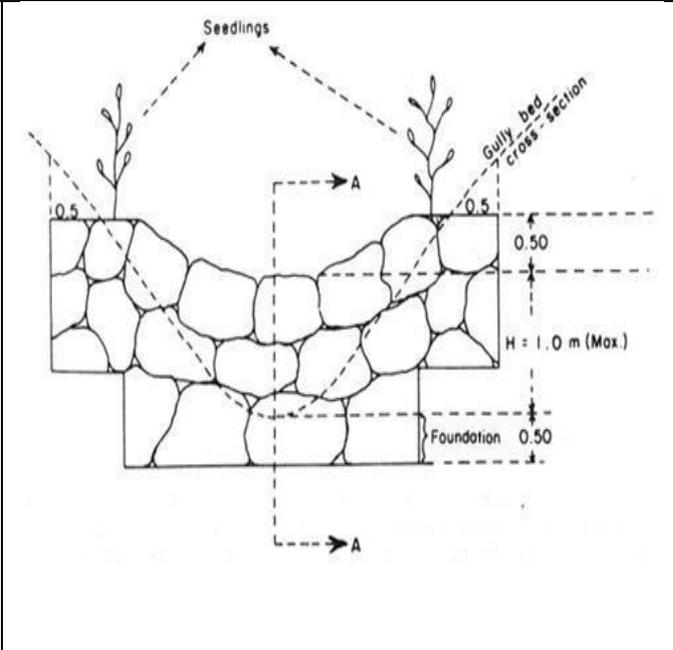
**Appendix 1- 6: loose stone check dam**

**General description:** Loose stone check-dam is a structure made of relatively small rocks and placed across the gully or small stream, which reduces the velocity of runoff and prevents the deepening and widening of the gully. Sediments accumulated behind this check-dam could be planted with crops or trees/shrubs, grasses and thus provide additional income to the farmer



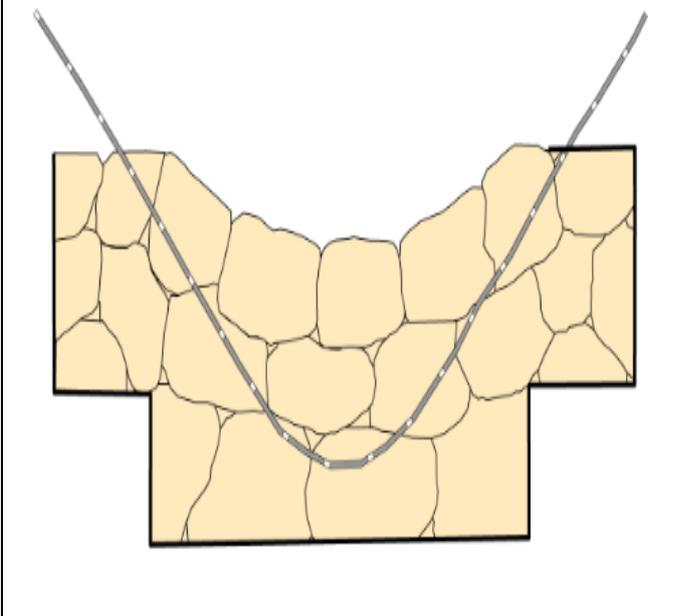
**Technical design steps/requirements**

- Bottom key and foundation; 0.5 m deep
- Side key: 0.5 – 1 m per side
- Height: 1 – 1.5 m excluding the foundation, mostly 1 m is suffice to avoid failures
- Base width: 1 m – 3.5 m
- Spill way (trapezoidal/parabolic): 0.25 – 0.5 m permissible depth and 0.25 m free board; and width of 0.5 – 1.2 m.
- Apron length should be at least 1.5 times of the effective height of the check-dam and as wide as the gully bed.
- The apron should be placed in an excavation of about 0.3 – 0.5 m to ensure stability and prevent wash away. A sill of about 15 cm should be constructed on the lower end of the apron.
- Proper spacing between the successive dams should be ensured



**Layout and construction procedures**

- Identify appropriate location in the gully where the bed slope is  $< 5\%$ , soil depth  $> 50$  cm and relatively wider locations of the gully. Cross-sections of gullies where the reservoir level requirement is not more than one meter is appropriate. Avoid locations where the gully is meandering/turning
- Collect stones necessary for the construction of the check dam.
- Peg and tie a string marking base width on the floor across the gully bed
- Excavate the foundation and place stones such that they interlock easily
- Construct the loose stone to a height of 1m excluding the foundation
- Construct a side key and a parabolic spillway
- Construct apron on the downstream side of the check dam to protect the dam from undercutting and include a sill on the lower end of the apron



**Appendix 1- 7: Gabion check dam**

**General description:** Gabions are rectangular boxes of varying sizes and are mostly made of galvanized steel wire woven into mesh. The boxes are tied together with wire and then filled with either stone or soil material and placed as building blocks. Gabions are filled in situ and as they are very heavy they will not be washed away provided they have been correctly installed.

The main advantages of gabion check-dams are that they are tough and long lasting provided that the wire has been well galvanized. Furthermore they are somewhat flexible and can be installed where the surface is uneven. They can be used to stabilize gully sides, gully heads, roadside embankments, River banks and even landslips.

**Technical design steps/requirements**

Gabion check-dams are built usually not higher than 1.5 m spillway height in the first year. After sediments have been deposited behind the structure, it is possible to raise the spillway height by adding additional gabion boxes. The foundation, apron, side key and spillway are the important parameters to be considered during designing of gabion check-dams.

- The selection of the proper mix of the various sizes of gabion boxes is also another parameter to be seen during design preparation.

No	Gabion size (m <sup>3</sup> )	2.5 mm wire (kg)	3.5 mm wire (kg)	Tying wire (kg)	Share of each size during construction (%)
1.	2 x 1 x 1 m	12.0	2.3	0.6	60
2.	2 x 1 x 0.5 m	8.5	1.7	0.5	20
3.	1 x 1 x 1 m	7.0	1.5	0.4	15
4.	1 x 1 x 0.5 m	3.4	0.9	0.3	5

- If stone is not available in close proximity, the gabion boxes can be mated in the inner part with plastic sheet and then filled with soil material. This will serve the purpose of stone filled gabion check-dam if properly constructed following design specifications.



**Layout and construction procedures**

**Appendix 1- 8: trench**

**General description:** Trenches are large and deep pits constructed along the contours with the main purpose of collecting and storing rainfall water to support the growth of trees, shrubs, cash crops and grass or various combinations of those species in moisture stressed areas (350-900 mm rainfall). Trenches can have flexible design, to accommodate the requirements of different species. Therefore, they can suit what the farmer want to grow. Trenches collect and store considerable amount of runoff water, thus vegetation grows faster and vigorous. They protect cultivated fields located downstream from flood and erosion. Part of the water captured by the trenches reaches the underground aquifer. Therefore, water tables are recharged and supply springs and wells with good quality water and for a long period of time (See Photos below). There are various trenches known by shape and size such as circular, square or trapezoidal and small or large.

**Technical design steps/requirements**

- It can be constructed to grow 1 or up to 3 trees in each trench. The designs of the trench depend from the type of soil, rainfall, and the type and position of trees;
- Take advantage of the water harvesting effect of the trench by planting 1 fast growing tree and 1 or 2 additional slow growing trees (which require less water);
- Catchment Area/Trench Area ratio CA/TA is 3-5:1 (based on rainfall and tree water requirements) – normally 2-3 meters distance between lines of trenches - ratio can vary depending on dryness;
- Trench with two trees planted on pits dug in two ties;
- Trench with 1 tree planted in a tie and

2 trees on pits dug in front of trench; f) Trench with 2 trees planted in two ties and 1 tree planted in front of the trench; g) They are constructed in a staggered position one from another (triangle); h) No of trenches/ha from 800-1200; and N.B. For further detail see Pictures below.



Trenches on gently sloping hillsides and grazing lands- Atsbi Wemberta, Tigray



Trenches constructed on farmlands above soil bunds – Atsbi Wemberta, Tigray

**Layout and construction procedures**

a) Start from the top of the hill or field; b) Using an A-frame (or other level) the same size of the trench (2,5-3 m long) level the two tips of the frame and then mark the shape of the trench; c) Continue marking more trenches with the A-frame adjacently and below the first one; d) Spacing between two trenches laterally is 25-50 cm; e) After layout dig soil to reach 20-25cm depth x 50cm width x 2,5-3m length (1); f) Keep some of the good topsoil aside for filling planting pit (s); g) Then dig a 50 x 50 cm wide x 40cm deep pit in the middle of the trench (2); h) Bottom of the pit should be 10-15 cm deeper than bottom of trench; i) Side ditches may slope towards ties for maximum utilization of light rain showers; j) Demarcate the tie around the pit (10cm from pit border on both sides) and proceed to deepen the collection ditch around the ties up to the required depth of 50cm (3); k) The embankment is to be shaped level and well compacted; and for more construction sequence



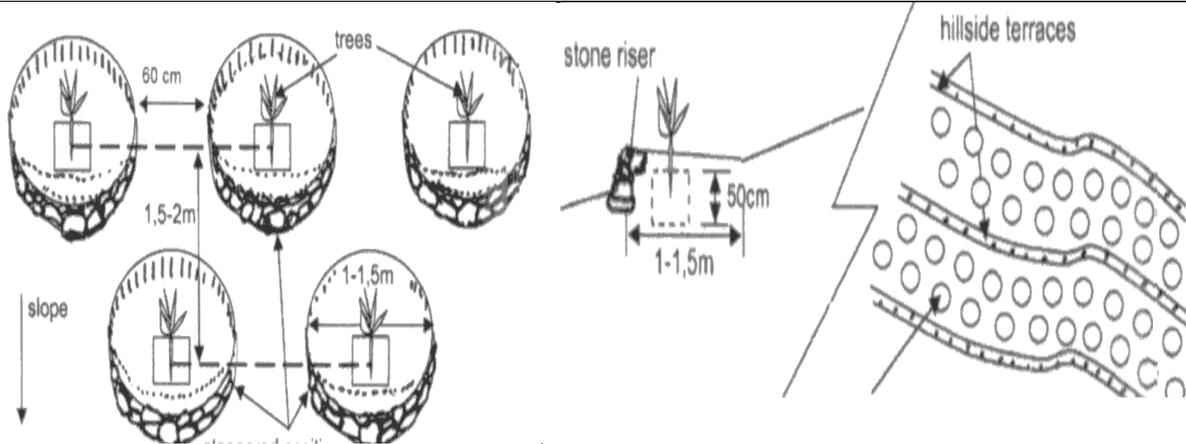
Trenches in a staggered arrangement (left) and recharging pits/trenches (right)

**Appendix 1- 9 micro-basin**

**General description:** micro-basins are small circular and stone faced (occasionally sodded) structures for tree planting. *Micro basins* are used in order to store *precipitation* water by collecting surface *run-off*. low soil ridges – optionally supported with stone walls - are constructed in an enclosed shape to form a basin, which helps to prevent the water to further run off. The collected rainwater is then used for direct *irrigation* or infiltration into the soil to enhance soil moisture and recharge *groundwater*. Also used for optimization of water use in agriculture, conservation of soil moisture, surface and groundwater recharge.

**Technical design steps/requirements**

Different design types are possible, including half-moon, v-shaped, diamond-shaped, trapezoidal, as well as contour *bund* basins. *Micro basins* are mostly used for small-scale tree and bush planting in areas with moisture deficit. Each basin consists of a catchment area and an infiltration pit, which serves as the cultivated area. The field can be additionally protected from excess water *runoff* with the construction of a cut-off drain or a retention ditch. V-shaped *micro basins* are also called “negarims”. They are particularly common for fruit tree production in drier areas of Ethiopia, Israel and in several districts of Kenya. The height of the ridges relies strongly on the slope and the size of the catchment. Technical standards: i) Diameter: to range from 1- 1.5 m; ii) Stone riser: 0.2m;iii) Foundation and height: 0.2-0.4m above ground based on slopes; iv) Plantation pit: 0.4m diameter x 0.5m depth; v) Soil sealing: sealed with soil from cut area; vi) Constructed in staggered position between rows and in rather close spacing within row in case of 1 m diameter basins.



Micro-basins in a staggered arrangement

Micro-basins between hillside terraces

**Layout and construction procedures**

i) Layout in staggered position; ii) Foundation; iii) Placement of stone raiser; iv) Cut and fill and seal required so that the water should not leak unnecessarily; v) Construction of plantation pit.

**Appendix 1- 10:: Grass strips**

**General description:** GS are narrow strips of naturally growing or planted grasses laid out on the contour or graded line. The width of the GS mainly depends on the density of the grass (vegetation) in the strip. When the line of grass is continuous and close, it does not allow much soil to pass through, thus, the soil is filtered out and deposited behind/in the upper slope of the strip. In this case, the width of the strip can be narrow. But if the plants in the strip are sparse and do not allow major deposition above the strips, the process of filtration and deposition of the soil particles would be graduated and take place throughout the width of the stripes. In this case, wider stripes allow more deposition of soil particles and more effective in controlling soil loss by runoff.

It is always preferable to use narrow stripes to economize the land and other resources provided the narrow strips are effective enough to control soil loss. In the high potential perennial cropping areas, the condition is favorable for fast and vigorous vegetation growth and hence for the formation of dense and effective GSs. In this type of climate, narrow GSs (not wider than 50cm) could be effective for erosion control. However, in semi-arid areas, the narrow GSs (e.g. 50cm wide) may not be applicable to effectively control erosion. Thus it is advisable to use the wider (1m) level GS where the technology is applicable. 1m VI is followed to layout and establish the GSs.

**Technical design steps/requirements**

**Forms of planting material:** There are various forms of planting material used for the establishment of vegetative barriers. The planting material can be seed or vegetative forms (e.g. seedlings, root splits, stem cuttings, etc). The vegetative forms like seedlings, root splits and stem cuttings are in growing process; they have more energy reserves and/or growing organs for better establishment and survival when planted out in the field. Therefore, when the vegetative forms are available and the transportation facilities and establishment costs are not discouraging, it is preferable to use vegetative forms. However, it could be difficult to use always the vegetative forms of planting materials because of the difficulties in transportation and high labor requirement. This is especially a problem when the transportation distance is far and a large area is to be covered in a Fir Kebso period. Thus, under this condition it would be advisable to consider the use of seeds too.

**Suitable species:** Grass species should be perennial and persistent, compete with and suppress weeds, provide good ground cover, provide physical impediment to flow and hence conserve the soil and moisture. They should have multiple values like fodder, in addition to soil and moisture conservation. The grass species suitable for grass stripes are as follows: In low rainfall areas grasses like vetiver, Sudan grass and other local grasses can be used whereas, in high rainfall areas; phalarisaqatica, Vetiver and local grass (e.g. pennisetum spp.) can give better results. .

**Layout and construction procedures**

**Planting technique:** Planting techniques slightly vary with different forms of planting material. While the use of seed allows flexibility of broadcasting and line/row planting, the use of vegetative forms of planting materials limits the techniques to line/row planting. The planting technique should always ensure good soil-seed/seedling contact.