

CLIENT



OROMIA IRRIGATION DEVELOPMENT AUTHORITY
Feasibility Study for Gura Erbe SSI Project in West Hararghe Zone
Oda Bultum Woreda

DRAFT FEASIBILITY REPORT OF WATERSHED MANAGEMENT

CONSULTANT



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

**April, 2019
FINFINNE**

TABLE OF CONTENTS

1. INTRODUCTION	5
1.1 GENERAL	5
1.2 GURA ERBE WATERSHED STUDY	6
1.3 OBJECTIVES OF THE STUDY	7
2. METHODOLOGY OF THE STUDY.....	8
2.1 GENERAL	8
2.2 DATA COLLECTION	8
2.3 WATERSHED DATA AND PROBLEM ANALYSIS	9
3. REVIEW OF STRATAGIES, POLICY AND PREVIOUS STUDIES.....	10
3.1 REVIEW OF PREVIOUS STUDIES	10
3.1.1 <i>Ethiopian Highland Reclamation Study</i>	10
3.2 RELEVANT POLICIES AND STRATEGIES	10
3.2.1 <i>Rural Land Use and Land Administration</i>	10
3.2.2 <i>Food security strategy (2002)</i>	11
4. BIOPHYSICAL FEATURES OF GURA ERBE WATERSHED AREA	12
LOCATION.....	12
4.1 WATERSHED CHARACTERISTICS	14
4.1.1 <i>Land Form and Slope</i>	14
4.1.2 <i>Drainage area</i>	16
4.1.3 <i>Shape of the Watershed</i>	16
4.2.2.1 <i>The circulatory ratio</i>	16
4.2.2.4 <i>Elongation ratio</i>	18
4.2 CLIMATE	22
4.3 LAND USE AND LAND COVER	24
4.4 TYPE, CAUSE AND EFFECT OF SOIL EROSION	28
4.4.1 <i>Assessment of Current Soil Loss</i>	28
4.5 NATURAL RESOURCES MANAGEMENT	35
4.6 SOCIAL SERVICE.....	ERROR! BOOKMARK NOT DEFINED.
5. HYDROLOGIC ANALYSIS AND SEDIMENT YIELD	36
5.1 SEDIMENT YIELD.....	36
5.2 HYDROLOGIC ANALYSIS	37
6. LAND CAPABILITY CLASSIFICATION	39
6.1 GENERAL	39
6.1.1 <i>Land capability Classification Result</i>	41
7. SOCIO-ECONOMIC CONDITIONS	45
7.1 FARMING SYSTEM.....	45
7.2 NATURAL RESOURCES MANAGEMENT.....	46
8. MAJOR WATERSHED PROBLEMS, POTENTIALS AND OPPORTUNITIES	47
8.1 WATERSHED PROBLEMS.....	47
8.1.1 <i>Soil Erosion</i>	47
8.1.2 <i>Low Livestock Production and Overgrazing</i>	47
8.1.3 <i>Deforestation</i>	48
8.2 EXISTING OPPORTUNITIES AND POTENTIALS	49
8.2.1 <i>Bio-physical opportunities</i>	49
8.2.2 <i>Socioeconomic Opportunities</i>	49
8.2.3 <i>Development Potentials</i>	50
9. WATERSHED DEVELOPMENT INTERVENTIONS	51
9.1 SELECTION AND COMPONENTS OF WATERSHED INTERVENTIONS	51
9.2 AGRONOMIC & BIOLOGICAL SOIL AND WATER CONSERVATION MEASURES ..	53

9.2.1	<i>Contour Cultivation</i>	53
9.2.2	<i>Crop Rotation</i>	53
9.2.3	<i>Compost and manure</i>	53
9.2.4	<i>Agro-forestry</i>	54
9.2.5	<i>Grass Strips</i>	54
9.3	PHYSICAL SOIL AND WATER CONSERVATION MEASURES.....	55
9.4	LIVESTOCK DEVELOPMENT.....	58
9.5	ALTERNATIVE INCOME GENERATING SCHEMES.....	58
9.6	ALTERNATIVE ENERGY TECHNOLOGY.....	58
9.7	ENERGY SAVING STOVE.....	59
9.7.1	<i>Solar lantern</i>	59
9.7.2	<i>Homestead tree plantation</i>	59
9.8	FAMILY PLANNING.....	60
9.9	ENVIRONMENTAL EDUCATION IN SCHOOLS.....	60
9.10	LOCAL CAPACITY BUILDING.....	61
10.	WATERSHED DEVELOPMENT PLAN AND BUDGET ESTIMATES.....	62
10.1	GENERAL.....	62
10.2	HOT SPOT AREAS, PRIORITIZATION OF INTERVENTIONS AND DEVELOPMENT PLAN.....	62
10.3	ACTIVITIES AND SCHEDULE.....	64
10.4	INPUT AND COST ESTIMATES.....	65
10.5	BENEFITS EXPECTED.....	68
10.5.1	<i>Economic Benefit</i>	68
10.5.2	<i>Social Benefit</i>	69
11.	IMPLEMENTATION STRATEGIES.....	70
11.1	WATERSHED LOGIC RESPECTED.....	70
11.2	SMALL AREA BASED APPROACHES.....	70
11.3	COST-SHARING.....	70
11.4	PARTICIPATION.....	70
11.5	EXTENSION SERVICE AND TRAINING.....	72
11.6	RECOGNITION OF THE ROLE OF WOMEN.....	72
12.	MONITORING & EVALUATION.....	73
12.1	MONITORING.....	73
12.2	EVALUATION.....	73
13.	CONCLUSIONS.....	75
	REFERENCES.....	76

LIST OF TABLES

Table 4-1: Micro watersheds and their Areal Coverage in upstream of proposed weir site	12
Table 4-2 : Slope Categories & Topography of Gura Erbe Watersheds upstream of proposed weir site .	16
Table 4-3: Shape parameter values of Gura Erbe Micro watersheds	19
Table 4-4: Twenty years mean monthly & annual rainfall of the Gura Erbe Watershed	22
Table 4-5: Twenty years mean monthly minimum & maximum temperature (⁰ c) in the project area.....	22
Table 4-6: Erodibility of dominant Soil Types.....	29
Table 4-7: C factor for Different Vegetation Classes	30
Table 4- 8: C factor for the Study Area	31
Table 4- 9: Management Factor Values	31
Table 4- 10 : Slope class and Corresponding K in LS factor (SCRIP,1996)	32
Table 4-11: Slope class and Corresponding K in LS factor for Gura Erbe Watershed	33
Table 4-12: Average annual soil loss (t/ha/yr) and degree of soil erosion in the study Watershed.....	34
Table 5-1: Sediment deliver ratio and estimated annual sediment yield at the study watershed outlet	36
Table 5-2 Maximum storm value (mm) in 24 hrs for T years returns period	37
Table 5-3: Summary of watershed parameters	38
Table 6-1 : Land resource data and Land Capability classification results	42
Table 6-2: Description of land capability units(LCU).....	43
Table 6-3: The Escobedo Land capability classification table used as guide for land capability classification.....	43
Table 6-4: The conversion table used for land capability classes, suffixed, and land capability units	43
Table 9-1: Summary of recommended development options according to LCC of Gura Erbe watershed	52
Table 9-2: Spacing between bunds.....	55
Table 9-3: Width of cultivated land on bench terraces at different.....	56
Table 9-4: Summary of technical standards, layout & vertical intervals for major physical conservation measure.....	57
Table 10-1 Legend for Shor SSIP Watershed Development Map.....	63

LIST OF FIGURES

Figure 4- 1: : Location and Drainage Map of the Watershed	13
Figure 4-2: Slope map of Gura Erbe Watershed	15
Figure 4-3: Soil Map of Gura Erbe Watershed.....	21
Figure 4-4 : Elevation Range and contour map of Gura Erbe Watershed.....	23
Figure 4-5: Land use/Land Cover type in lower part of the watershed /around of the weir site.....	25
Figure 4-6 : land use/land cover type (Perennial crop) of the middle and upper part of study watershed	25
Figure 4-7: Land us/land cover type (Perennial crop) of the middle and upper part of study	26
Figure 4-8: Land Cover map of Gura Erbe Watershed	27
Figure 4- 9: USL factors(Erosivity, erodibility, slope Length, C factor and P factor).....	34
Figure 4-10: Soil Loss Status in the Watershed.....	35
Figure 8-1: Land cover immediately upstream of Gura Erbe Irrigation scheme weir Site	48
Figure 9-1: Design of Soil Bund.....	56
Figure 10-1: Watershed Development Map of Gura Erbe Watershed.....	63

1. INTRODUCTION

1.1 GENERAL

Any water development works such as weir, dam and water reservoir should be integrated with watershed management. In this regards, watershed management contributes to control soil erosion and maintain land productivity in the watershed and reduce sediment inflow to downstream areas and water resource infrastructures .This will also ensures equity of benefits from development interventions among upstream and downstream community.

In Ethiopia, watershed degradation is mainly caused by deforestation, rapid population growth and expansion of cultivation in to marginal lands and traditional farming practices. Generally steep topography, intense rainfall pattern, fragile nature of the soils, vegetation cover, and management practices are the main factors that influence soil erosion and land degradation process in most watersheds throughout regions of the country.

These are manifested in decline of soil fertility, loss of vegetation cover, soil moisture stress, land losses due to dissected gullies and land sliding problems, decrease in the yield of groundwater sources and shortages in various forest resources, which in turn leads to progressive decline of overall land productivity.

The primary causes for this destruction are high population growth, uncontrolled cutting of trees for various purposes notably fuel wood, charcoal, construction, and the spread of expansion of cultivation both in shifting and sedentary agriculture. The high livestock population coupled with exploitive type of grazing land management system is the other aggravating factors for destruction of forest resources in the country. Generally, forest clearing, improper farming and overgrazing have taken their toll and land productivity and downstream economics in most cases in the country. To reverse this situation and to ensure sustainable land management, implementation of participatory watershed management is indispensable.

Recently, the government of Ethiopia has put strategy which, any water development projects should be integrated and linked with participatory watershed management that should be carried out following watershed logics disclose that implementation of interventions should be start from upper part of the watershed to bottom or lower part of a watershed for ensuring sustainable the natural resources management and increase land productivity in the watersheds.

Thereby to reduce sediment inflows to downstream receiving water bodies or reservoir and planned irrigation development schemes.

1.2 GURA ERBE WATERSHED STUDY

Similar to other parts of the country, there is a sign of soil erosion and decline of soil fertility in Gura Erbe watershed especially on intensively cultivated lands. However, soil erosion not severe due to perennial crop based farming system mainly banana and chat based farming system in upstream of spring parts of the Boke and Oda Boltum weredas that contributed in reducing soil erosion through keeping the soil covered for most of the time. Soil erosion associated with increasing population pressure and climate changes expected to exacerbate in the future. Therefore, it is essential to integrate watershed management as one of the major components of the Gura Erbe Irrigation development project.

In view of this, Gura Erbe watershed management study was conducted by OWWDSE Consultant as part of the feasibility studies & detail design of small scale irrigation schemes.

The Gura Erbe watershed management study report describes the background information, review of literature, findings of assessment of the biophysical and socio-economic features of the watershed governing soil erosion and conservation in the watershed, potentials, opportunities problems and constraints and proposing watershed development interventions.

Increased vulnerability to soil erosion hazard on steep slope, low livestock production and productivity, deforestation, low crop diversity and productivity and inadequate alternative income sources, increased fuel wood and construction wood demand, inadequate fuel wood supply are some of the watershed increased fuel wood and construction wood demand, inadequate fuel wood supply are some of the major problems in the Gura Erbe watershed.

A broad range of possible interventions and techniques are recommended to solve major problems in the watershed. Agronomic & biological and physical soil and conservation measures, livestock development, alternative income generating schemes, alternative Energy technology, and family Planning, environmental Education in schools and local capacity buildings are some of the intervention measures proposed to solve major watershed problems.

1.3 OBJECTIVES OF THE STUDY

The overall objective of this study is assessment of biophysical and socio-economic potential, constraints, land and water resources degradation status and existing resources management practices in the watershed and to give appropriate development options that could reverse current situations of the watershed , increase the productivity of agricultural lands ,protection of the existing natural resources in the watershed from further degradation and protection of downstream water infrastructures and other water bodies from siltation .

The specific objectives include-

- to assess the biophysical and socio-economic constraint and potentials of the watershed
- to carryout land capability classification to identify the soil and water conservation requirement classes
- to determine the extent and severity of soil erosion and land degradation
- to prepare integrated watershed development plan along with institutions responsible for the implementation of the development plan and
- to estimate the cost required for implementing the proposed watershed management plan

2. METHODOLOGY OF THE STUDY

2.1 GENERAL

Watershed management study involves inventory of biophysical resources and assessing socio-economic and institutions relevant to watershed management study. Accordingly, various data collection methods were used in collecting data for Gura Erbe watershed management study. Data collection and problem analysis method is used to enable us characterize biophysical and socioeconomic conditions of the watershed.

2.2 DATA COLLECTION

The watershed boundary was delineated using 1:50,000 scale topographic map and 30 m by 30m resolution digital elevation model (DEM) by using ARCGIS. Based on the delineated watershed boundary, secondary information on agro-ecology, soil types and land use/cover has been collected through review of previous studies. Subsequently, field visits were carried out in the watershed to ascertain the secondary information and collect necessary data.

Pictures were also taken to have general over view of the landform, land cover and deforestation situations in the watershed area for references. Through transect walk, data have been collected and checked with secondary information on land use /land cover types, soils, vegetation cover, topographic features, soil erosion and land degradation problems, types of current SWC measures and farming system in the area.

The main sources of information were obtained through referring different materials and intense discussions with the respective Woredas and targeted community members.

Discussions were conducted with staff of target Woredas' office. The discussion points include major problems of the watershed areas, adopted interventions and implementation strategies, sustainability of the implemented SWC measures, implementation of the recently enacted land use proclamations, and identification of possible options for the watershed management.

The specific methodologies and procedures used were the following:

- review previous studies and collection of available data required for watershed management study including soil types, agro-ecology and land use/ land cover with field checks in some part of the watershed area
- The watershed boundary was delineated using topographic map of 1:50,000 scale.

- Contour maps and slopes were generated from 30 by 30 m DEM. The digital elevation model (DEM) was used also to analyze the drainage patterns of the watershed. More over DEM was used to determine slope length and elevation ranges of the watershed
- Site observation were carried out in some part of the watershed and some data collected through focus group discussion and key informant consultation.
- Bio-physical and socio-economic data were collected from relevant government organization with pre-designed format
- Soil erosion status of the watershed was assessed through reviewing past study and using USLE adopted to Ethiopian condition.
- Land capability classification was carried out and analyzed using Escobedo land capability classification method adopted to the Ethiopian condition to identify soil conservation requirement classes
- Problem analysis and recommendations were made based on biophysical and socio-economic features of the watershed, and consultation results. It further analyzed based on regional and country experiences

2.3 WATERSHED DATA AND PROBLEM ANALYSIS

Land capability classes, gross soil loss, sediment yield analysis, watershed shape and agro ecology of the area were some of methods applied in analyzing the watershed problems, potentials and selection of watershed management interventions and development maps and prioritization of micro watersheds. The Land capability classification was done based on guidelines for watershed management planning in Ethiopia. Assessment of soil erosion in the watershed was made based on the Universal Soil Loss Equation (USLE), which is adapted to the Ethiopian condition. . Finally, the watershed management options, watershed management plans and development maps were identified by combining the result of these analyses.

Geographic information system (GIS) was used to interpret, analyze, visualize the land features (soil, land cover, slope and land capability classes, soil erosion, elevation etc.) and to produce various thematic maps.

3. REVIEW OF STRATAGIES, POLICY AND PREVIOUS STUDIES

3.1 REVIEW OF PREVIOUS STUDIES

3.1.1 Ethiopian Highland Reclamation Study

The Ethiopian highlands Reclamation study (EHRS, 1985) covered high land area having elevation above 1500 m.a.s.l. The main objective of the study was to identify the extent of land degradation and soil erosion problems. Soil erosion by water is the dominant type of soil erosion in Ethiopia and is the most important cause of soil erosion in Ethiopian Highlands the Ethiopian Highland Reclamation (EHRS) estimated that nearly 1.9 billion tons of soil is lost from highlands annually through water erosion alone.

According to EHRS 50% of the highlands are significantly eroded and more than 25% of the highlands of the country are seriously eroded. The study recommended the need to incorporate soil and water conservation intervention as an integral part of the farming systems.

This study was conducted at small-scale level and the study estimated moderate degree of erosion with an estimated annual soil loss of 113-539 t/ha/yr in Gura Erbe watershed.

3.2 RELEVANT POLICIES AND STRATEGIES

Policies issued by the Federal Democratic Republic of Ethiopia are a framework for policy development of regional states. In this regard, ‘agriculture led industrialization’ is umbrella policy, which other agricultural and rural development related policies could be Stemmed. The following are some of the policies and strategies of which have been reviewed and important for watershed management.

3.2.1 Rural Land Use and Land Administration

The Federal Government enacted rural land use and administration proclamation in July 2005 with a proclamation no. 456/2005. It is under this legal bases land certification and use right is issued to land users. The Federal governments has supported the strengthening of land use rights of farmers by conducting a certification program as one means to encourage them to invest on proper land management activities. Accordingly, Federal and regional state governments have supported the strengthening of land use rights of farmers by conducting a certification program as one means to encourage them to invest on proper land management activities.

The proclamation states that,

All peasant farmers and pastoralists have the right to use rural land free of charge and that this can be donated or inherited within a family.

Communal land can become private land as may be necessary and Article 5.4 indicates that peasant farmers, pastoralists and semi pastoralists have priority in rural land allocation but that, a) private investors have rights to rural land use in accordance with investment policy and law and, b) that government and non-government organizations have the right to use rural land in line with their development objectives.

there is no time limit to the land use rights of peasants, pastoralists and semi-pastoralists but that for other organizations the duration shall be determined by regional laws and that in the case of land requisition, compensation will be paid proportional to developments made on the land but not on any value of the land itself.

The obligations of the land users and indicates that holders shall be obliged to use and protect their land and that the use right will be lost if the land is damaged.

It also indicates that a land use master plan should be prepared and implemented using a watershed approach and that an equitable water use should be established between upper and lower watershed communities. It then states that:-

- free grazing is prohibited on any lands where soil and water conservation works have been undertaken and cut and carry is to be introduced gradually
- lands with slopes of <30% will be subject to soil conservation and water harvesting
- lands with slopes of 31-60% will only be allowed to be used for annual cropping if bench terraced
- lands with slopes of >60% will not be used for farming or free grazing but are reserved for forestry, agro-forestry, perennial cropping and forage production
- area closure will be implemented on degraded areas with compensation paid to previous land users
- gullied areas will be rehabilitated by individuals and communities

3.2.2 *Food security strategy (2002)*

The strategy has been placed on environmental rehabilitation through soil and water conservation, agro-forestry and reforestation to reduce the effect of degradation, increase production and productivity, and generate income. The strategy also includes water harvesting and the introduction of high value crops and livestock development.

It highlighted the importance of sustainable use of the natural resources for improving land productivity and overall agricultural production and ultimately achieving the food security.

The food security program has the following components, namely agriculture, (crop. livestock), small-scale irrigation; infrastructure/rural roads; sustainable use of natural resource base; market & credit services; clean water supply; and capacity building.

It is under the aforementioned legal basis that successful implementation of proposed watershed management interventions could be achieved,

4. BIOPHYSICAL FEATURES OF GURA ERBE WATERSHED AREA

LOCATION

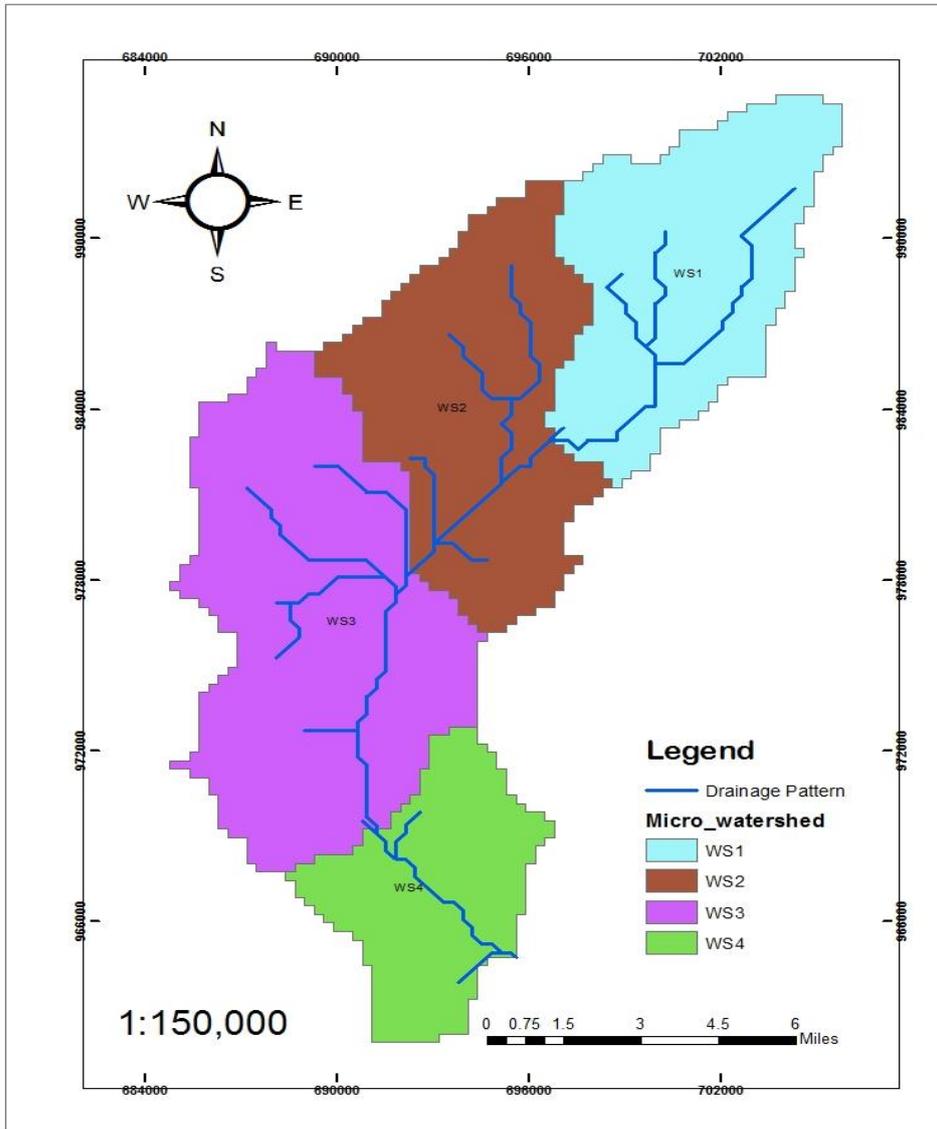
The Gura Erbe watershed is located in Oromia's regional state in West Hararghe Zone. It is specifically located in Oda Bultum and part of Boke Woreda.

Gura Erbe watersheds is subdivided in to four micro watershed namely WS1, WS2, WS3 and WS4 micro watershed at which watershed management interventions are to be implemented.

Table 4-1: Micro watersheds and their Areal Coverage in upstream of proposed weir site

No.	Code of micro watershed	Area(ha)	% coverage
1	WS1	7434	23.6
2	WS2	7983	25.3
3	WS3	11367	36,1
4	WS4	4743	15
Total		31527	100

Figure 4- 1: : Location and Drainage Map of the Watershed



4.1 WATERSHED CHARACTERISTICS

4.1.1 Land Form and Slope

Characterization and identification of landform and topography of a watershed helps in understanding of the erosion process, hazards and hence helps to identify the management possibilities. These characteristics of a watershed could influence on the hydraulic potentials of the area and in turn soil erosion hazardous in the watershed and levels of runoff generating capacities and sediment inflow to downstream areas.

The major land forms of the Gura Erbe watershed includes flat to gently undulating plains and plateau, steep escarpments and rolling hills.

Generally, the Gura Erbe watershed comprises flat to gently undulating topography (0-5 %), undulating /sloping land (5-10%), rolling, strongly sloping (10-25%), moderately steep (15-25%), steep (25-35) and very steep topography (>35%). This classification of slope is useful tool for land capability classification to identify soil conservation requirement classes and limitations of the watershed area. Slope has a major implication on soil erosion. It determines direction, speed, detachment and transportation of soil particles. Table 4-2 below presents slope category of Gura Erbe watershed

Figure4-2: Slope map of Gura Erbe Watershed

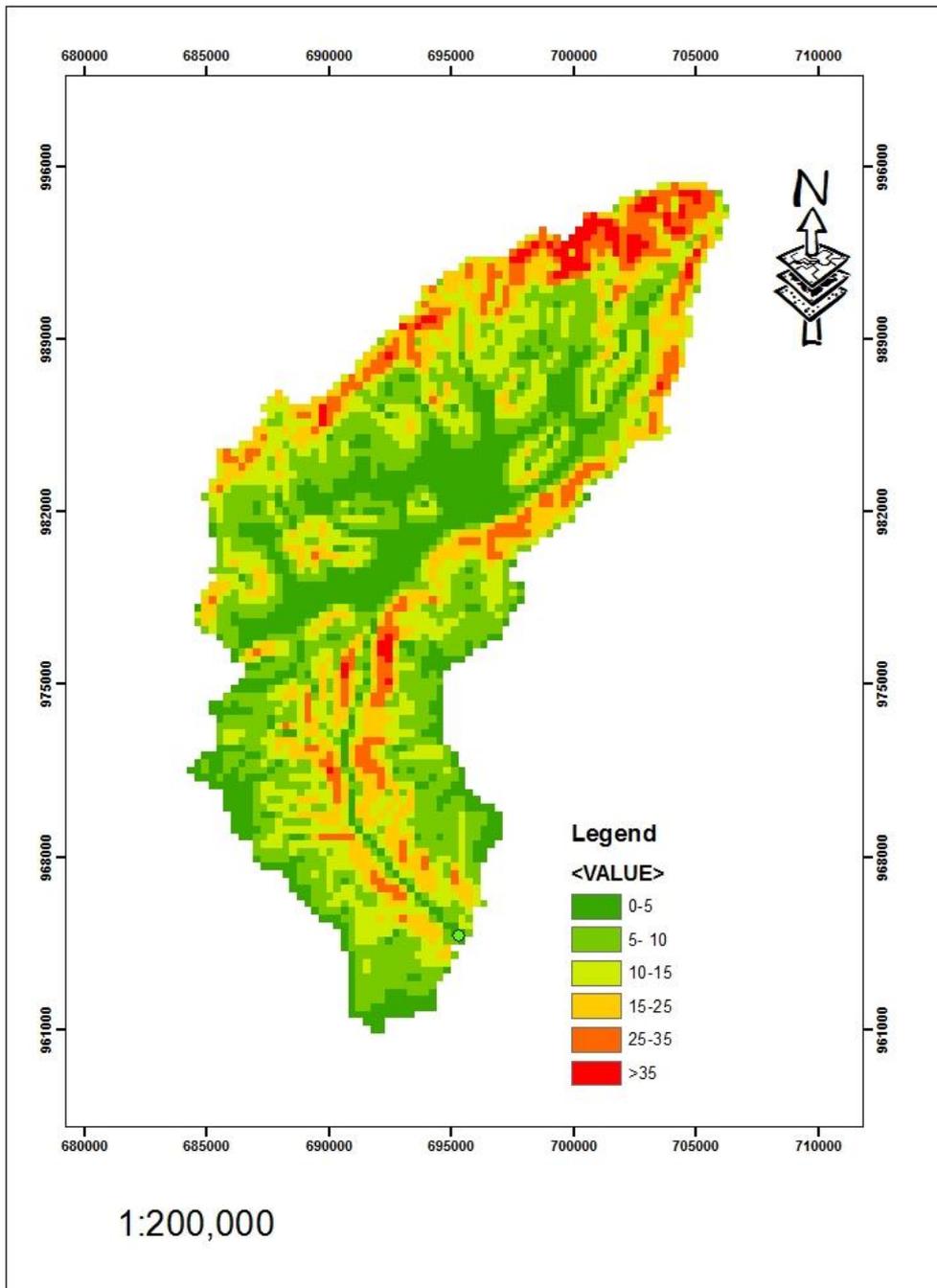


Table 4-2 : Slope Categories & Topography of Gura Erbe Watersheds upstream of proposed weir site

Slope Class (%)	Topography
0-5	Flat to gently sloping
5-10	Undulating, Sloping
10-15	rolling, strongly sloping
15-25	moderately steep
25-35	Steep
>35	Very Steep
Total	

Other important watershed characteristics relevant to watershed management are highlighted in the following section.

4.1.2 Drainage area

The drainage area (A) is one of the single most important watershed characteristic for hydrologic design. It reflects the volume of water that can be generated from rainfall. It is common in hydrologic design to assume a constant depth of rainfall occurring uniformly over the watershed. Under this assumption, the volume of water available for runoff would be the product of rainfall depth and the drainage area. Thus the drainage area is required as input to models ranging from simple linear prediction equations to complex computer models.

4.1.3 Shape of the Watershed

Watersheds have an infinite variety of shapes, and the shape supposedly reflects the way that runoff will bunch up at the outlet. A circular watershed would result in runoff from various parts of the watershed reaching the outlet at the same time. An elliptical watershed having the outlet at one end of the major axis and having the same area as the circular watershed would cause the runoff to spread out over time, thus producing a smaller flood peak than that of the circular watershed. The soil erosion rate and rate of sediment production were affected by the shape of the watershed that controls the time taken for run-off to concentrate at the outlet and the drainage pattern of a micro-watershed.

The following are some of the methods used to determine the shape of a watershed. The calculated values for each shape parameter are show in table 4-3 below.

4.2.2.1 The circulatory ratio

The circulatory ratio (R_c) describe the shape of the basins. The circulatory ratio is dimensionless. It is obtained from the ratio of the area of the basin to the basin perimeter using the following equation:

$R_c = 4\pi A/L_p^2$ Where A is the basin area; L_p is the perimeter of the watershed.

Miller (1953) has described the basin of the circularity ratios range 0.4 to 0.5, indicates highly permeable homogenous geologic materials present in the area.

In the study micro watersheds of Gura Erbe, the R_c value of the three micro watershed falls below 0.4 which indicates indicated the micro watersheds are elongated in shape. In this type of shape, (fern leaf watershed the time of concentration is more since the discharge is distributed over long period.

4.1.3.1 Compactes coefficient

Compactness coefficient (C_c) used to express the relationship of a hydrologic basin with that of a circular basin having the same area as the hydrologic basin. A circular basin is the most hazardous from a drainage standpoint because it will yield the shortest time of concentration before peak flow occurs in the basin.

The compactness coefficient, C_c , obtained from the ratio of the perimeter of the watershed to the area of the basin (Gravelius, 1914).

$C_c = 0.282L_p/A$ Where L_p is the perimeter of the basin; A is the area of the basin

When a watershed is a perfect circle, C_c will equal to one. The closer a compactness coefficient is to one, the greater the likelihood that precipitation will be quickly concentrated in the main channel, resulting in peak flows. C_c indirectly related with the elongation of the basin area. Lower values of this parameter indicate the more elongation of the basin and less erosion and vice-versa.

The compactness coefficients of the WS1, WS2 WS3 and WS3 micro watershed are 1.98, 1.73, 1.45 and 1.6 respectively .These values are found to be higher than unity which suggests that the shape of each study micro watersheds is elongated .

4.1.3.2 Form factor

If the basin or micro watershed is wider, the form factor will be comparatively higher. Consequently, much narrower basins have low form factor values. The low form factor indicated in the elongated basin and high form factor indicated in the wider basin.

Form factor (F_f) = $R_f = A / (L_b)^2$ where, F_f =form factor A=area of the basin, km^2

L_b =basin length

The value of form factor would always be less than 0.7854 for a perfectly circular basin. The smaller the value of the form factor, the more elongated will be the basin. . In the study, a micro watershed the form factor (Ff) is in the range of 0.08-0.2 indicating that the micro-watersheds is elongated in shape and has lower peak flow of longer duration as suggested by Chopra et al. (2005). The elongated micro watershed with low value of Ff indicates that the micro watershed will have a flatter peak flow for longer duration. Flood flows of such elongated micro watershed are easier to manage than from the circular watersheds.

4.2.2.4 Elongation ratio

Elongation ratio (Re) is the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin.

$Re = 2 / L_b * (A / \Pi)^{0.5}$ where L_b length of the basin/watershed, "A" area of the basin/watershed, $\Pi = 3.14$

Analysis of elongation ratio indicates that the areas with higher elongation ratio values have high infiltration capacity and low runoff. A circular basin is more efficient in the discharge of runoff than an elongated basin.

The values of elongation ratio generally vary from 0.6 to 1.0 over a wide variety of climate and geologic types. Values close to 1.0 are typical of regions of very low relief, whereas values in the range 0.6 to 0.8 are usually associated with high relief and steep ground slope (Strahler ,1964). These values can be grouped in to three categories namely (a) circular (>0.9), (b) oval (0.9 to 0.80), (c) less elongated (<0.7).

The elongation ratio values of WS1, WS2 W3 and W4 micro watersheds are 0.74 0.95 0.75 and 1.3 respectively which reveals elongated shape. Gura Erbe WS4 micro watershed has relatively high elongation ratio values which indicates that this micro watershed is elongated associated with relatively high relief and steep slope.

4.1.3.3 Water shed Length

The length (L) of a watershed is the second watershed characteristic of interest. While the length increases as the drainage increases, the length of a watershed is important in hydrologic computations. Watershed length usually defined as the distance measured along the main channel from the watershed outlet to the watershed divide. The length usually used in computing a time parameter, which is a measure of the travel time of water through a watershed.

Table 4-3: Shape parameter values of Gura Erbe Micro watersheds

No.	Name of Micro watershed	Area (km ²)	Perimeter (km)	Length (km) (Lb)	Shape parameter Values			
					Circularity ratio (Rc)	Compactness coefficient (Cc)	Form factor (Ff)	Elongation ratio
1	WS1	74.34	49.8	7.4	0.41	1.98	0.03	0.74
2	WS2	79.8	55.2	6	0.36	1.73	0.03	0.95
3	WS3	113.7	61.8	9.1	0.4	1.45	0.03	0.75
4	WS4	47.73	39	3.4	0.43	1.6	0.031	1.3

Major Soils

Soils have particular importance in watershed management. The significances of soils characteristics, which influence the process within watershed, are soil permeability, soil erodability and compositions of nutrients that help vegetative growth. These characteristics are influenced mainly by soil properties such as soil texture, structure, depth, organic matter content, soil fertility, soil reaction, soil colour and stoniness. These properties of soils are highly important parameters in watershed development planning. The decisions taken during the planning process ought, therefore, to reflect at least a basic level of knowledge about the soil conditions.

Together with climate and terrain, soil conditions determine what agricultural production possibilities exist in a given area from a biophysical perspective. Soil erosion also depends greatly on the infiltration rate of soil. The infiltration rate again depends on the soil texture, structure, humus and, moisture content, soil depth and surface roughness. Soil conservation structures used for rehabilitation of degraded lands recommended based on the aforementioned soil properties

Vertisols have strong brown or red B-horizon. Such types of soils possess vertic properties, containing a high content of swelling clays that crack in the dry season, and swell in the rainy season causing impeded drainage. Vertisols have a fairly good but limited agricultural potential because the land is rather difficult to prepare. Dry soils are hard and wet soils are very sticky. Vertisols are widespread in the slopes in the form of pellic in the watershed. They are broadly distributed and found commonly as pellic Vertisols in the part of the catchment (see Figure below). Pellic Vertisols are dark, almost black. Vertisols are most difficult soils in management. They have black color and originate from volcanic or volcanic sediments. Vertisols are characterized by 5.5-8.2 pH, with very high CEC, more than 50 cm deep, poor drainage and difficult workability. These soils are often referred to as problematic soils owing to the behavior

of creating difficulties for cultivation. However, the soils have high agricultural potential under fertile conditions, because of their nature to hold moisture for longer period. Run-off formation from Vertisols is high and hence Vertisols are susceptible to erosion unless properly managed. It becomes apparent that undertaking structural conservation measures is difficult on Vertisols owing to the instability of such soils. The organic matter content of Vertisols is often no more than 0.5 – 1.0%.

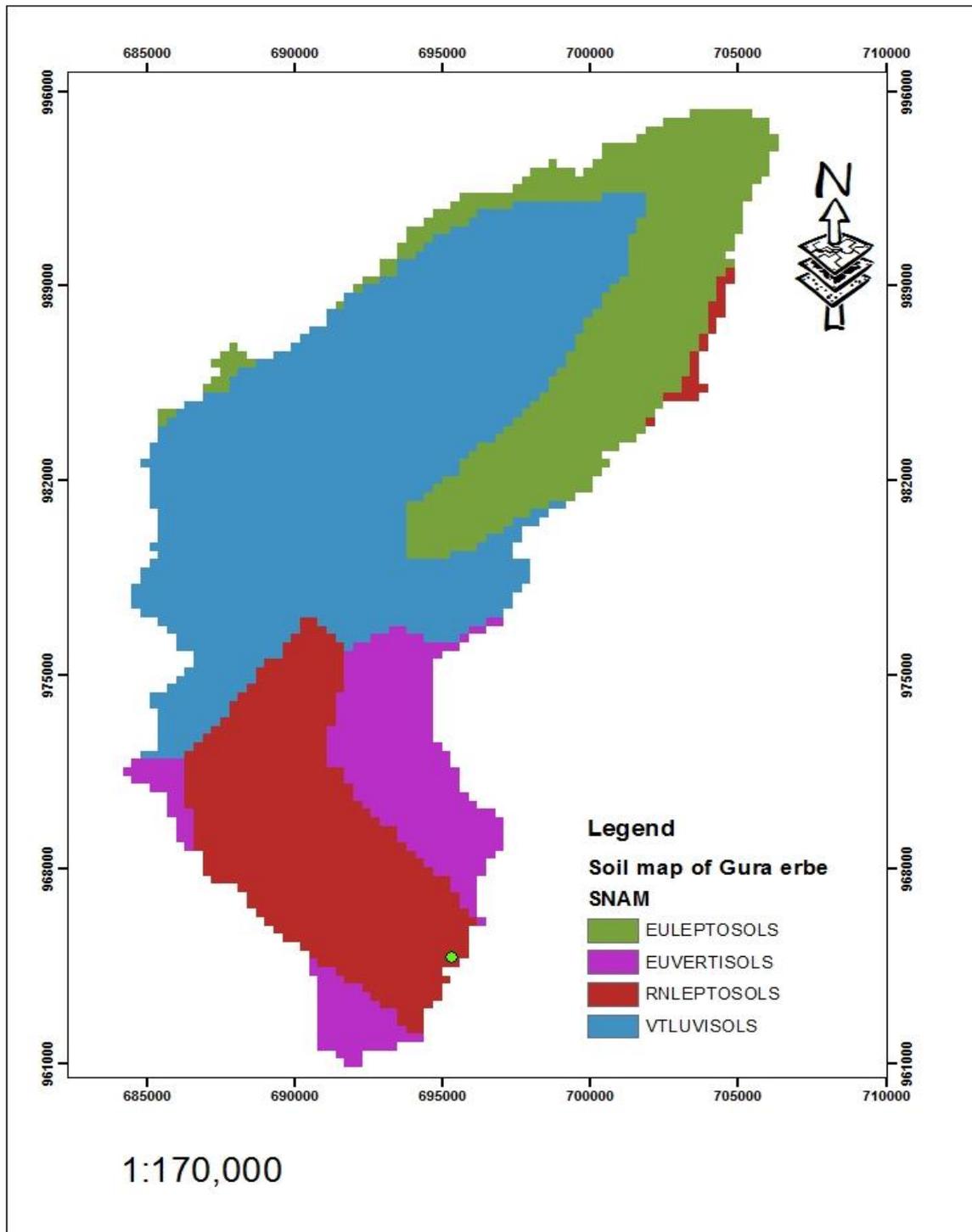
Eu vertisols and VT Luvisols are the other the major soils of Gura Erbe Watershed. VT Luvisols dominantly found on upper part and while the chromic Luvisols occupy only the lower Part of Gura Erbe Watershed .

Luvisols are soils having an agric horizon, which has a base saturation of 50% or more at least in the lower parts of the B-horizon. These soils show textural differentiation in the profile showing surface horizon depletion in clay and clay accumulation in the sub surface and moderate to high clay activity.

The Luvisols are moderately deep to very deep, well drained, with moderate to strong, granular, crumb and sub angular blocky structure, clay and clay loam textured soils. These soils show textural differentiation in the profile showing surface horizon depletion in clay and clay accumulation in the sub surface and moderate to high clay .The luvisol occurring on flat to gently sloping topography are very deep and those on steep topography modernly deep.

The soil map of the watershed was obtained from Ethio Soil map study document and clipped using ARC GIS 10.4 by overlaying the study watershed and the soil map.

Figure 4-3: Soil Map of Gura Erbe Watershed



4.2 CLIMATE

Climate is the main agent determining the water balance and it largely determines the natural vegetation, and interactions of climate, relief, and soils are particularly important for watershed management. The main climatic information that is important for watershed management is rainfall, temperature, and others like evapo-transpiration, relative humidity, solar radiation etc. The study area receives 1087 mm mean annual rainfall. More than 40 % of the annual rainfall occurs in the period of July to September, the maximum being in the month of August.

The rainfall distribution of the area has been estimated from stations around the watershed and from grid data. The mean monthly rainfall distribution of the relevant stations is indicated below in Table 4-4

Table 4-4: Twenty years mean monthly & annual rainfall of the Gura Erbe Watershed

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Galamso	11.4	16.6	62.2	136.7	103.5	76.4	152.9	187.7	137.7	57.7	33.6	15.3	991.7
Badessa	14.4	7.1	81.5	137.7	125.4	127.7	182.6	157.0	158.1	137.4	36.9	16.4	1182.3

Source: Hydrology report of Gura Erbe watershed

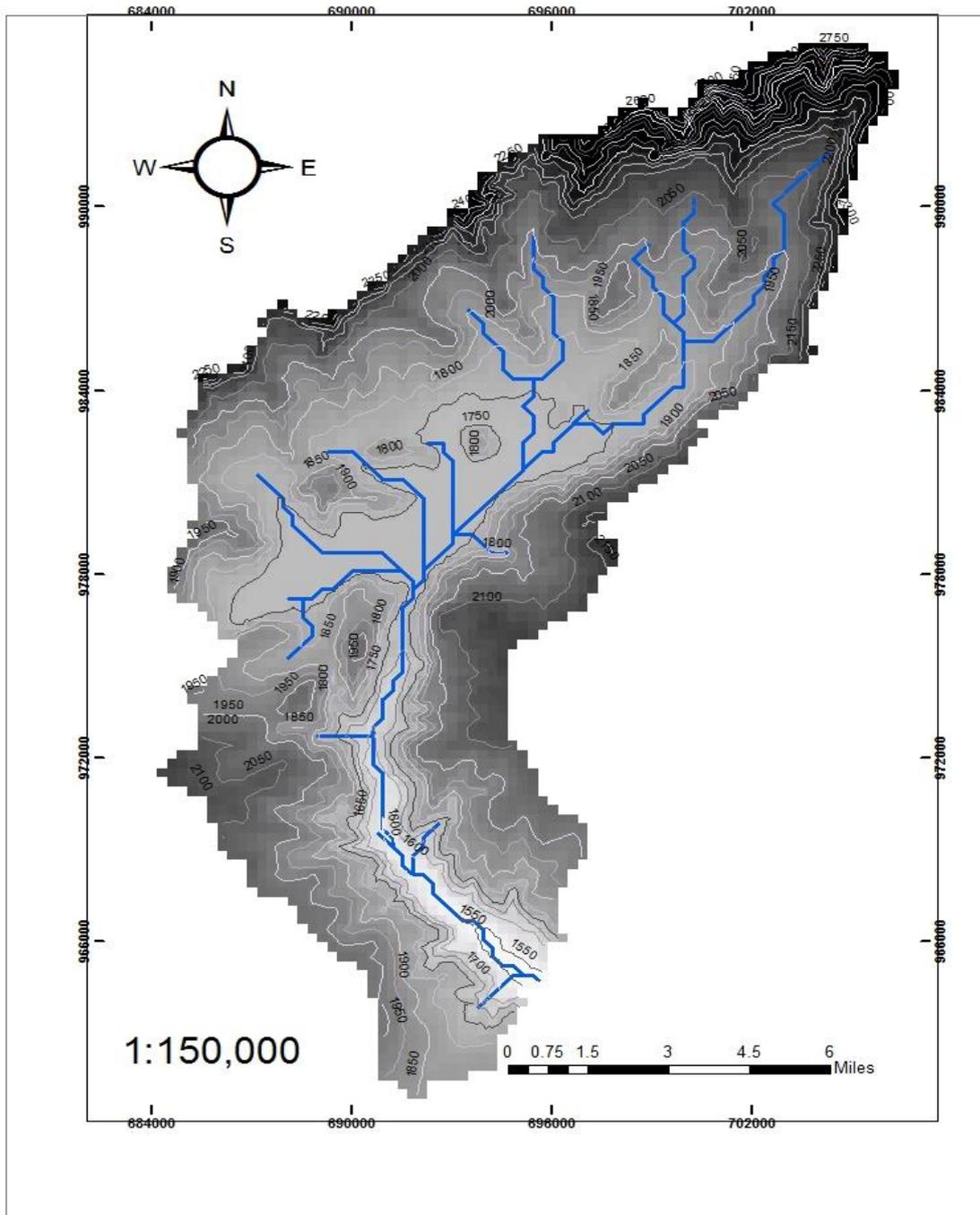
The mean minimum and maximum temperature of the study area varies from 13.8-17.3°C and 26.2- 28.4°C, respectively. The mean monthly minimum & maximum temperature of the study area is presented below in table 4-5.

Table 4-5: Twenty years mean monthly minimum & maximum temperature (°c) in the project area

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max	26.9	28.4	28.27	27.1	27.6	27.0	26.2	26.4	26.4	26.8	27.2	26.5	27.1
Min	15.0	15.5	17.3	17.1	17.2	17.2	17.1	17.1	16.6	15.5	13.8	14.0	16.1

Source: Hydrology report of Gura Erbe watershed

Figure 4-4 : Elevation Range and contour map of Gura Erbe Watershed



4.3 LAND USE AND LAND COVER

Land Cover

Soil erosion and land degradation depends on the land cover and land use type of a given area. Land with a good vegetation cover is resistant to erosion compared to bare land. That vegetation plays multiple effects that include intercepting raindrops, reducing surface runoff, and there by control erosion, maintain soil fertility and maintain the environment. Vegetation cover also helps to enrich ground water sources. Moreover, a plan of watershed management based on the land use type along the climatic and other physical factors that define the situation.

The land use practices such as improper cultivation and over grazing land management practices are also contributing factors for soil erosion and land degradation problems.

Of all land cover type, Agricultural lands cover about 52 % of and Bush land 38.2 % and forestland 9.8% of the watershed.

Land Use

Annual and perennial crop cultivation, grazing, tree planting, fire and construction wood collection are land use types in the watershed.

Perennial and annul crops are cultivated around homesteads. The perennial crop cultivation found throughout the watershed. The farm village farm is relatively well managed and utilized in sustainable manner by cultivating multi story crops.

Perennial crops make significant contribution to soil fertility management and conservation .The type of perennial crop and proportion varies within the watershed .Perennial crops such as bananas, chat, avocado and coffee are predominant in the lower and middle part of the watershed, while, bananas, cereals; and limited chat are increasing in the higher altitude of the upper watershed.



Figure 4-5: Land use/Land Cover type in lower part of the watershed /around of the weir site

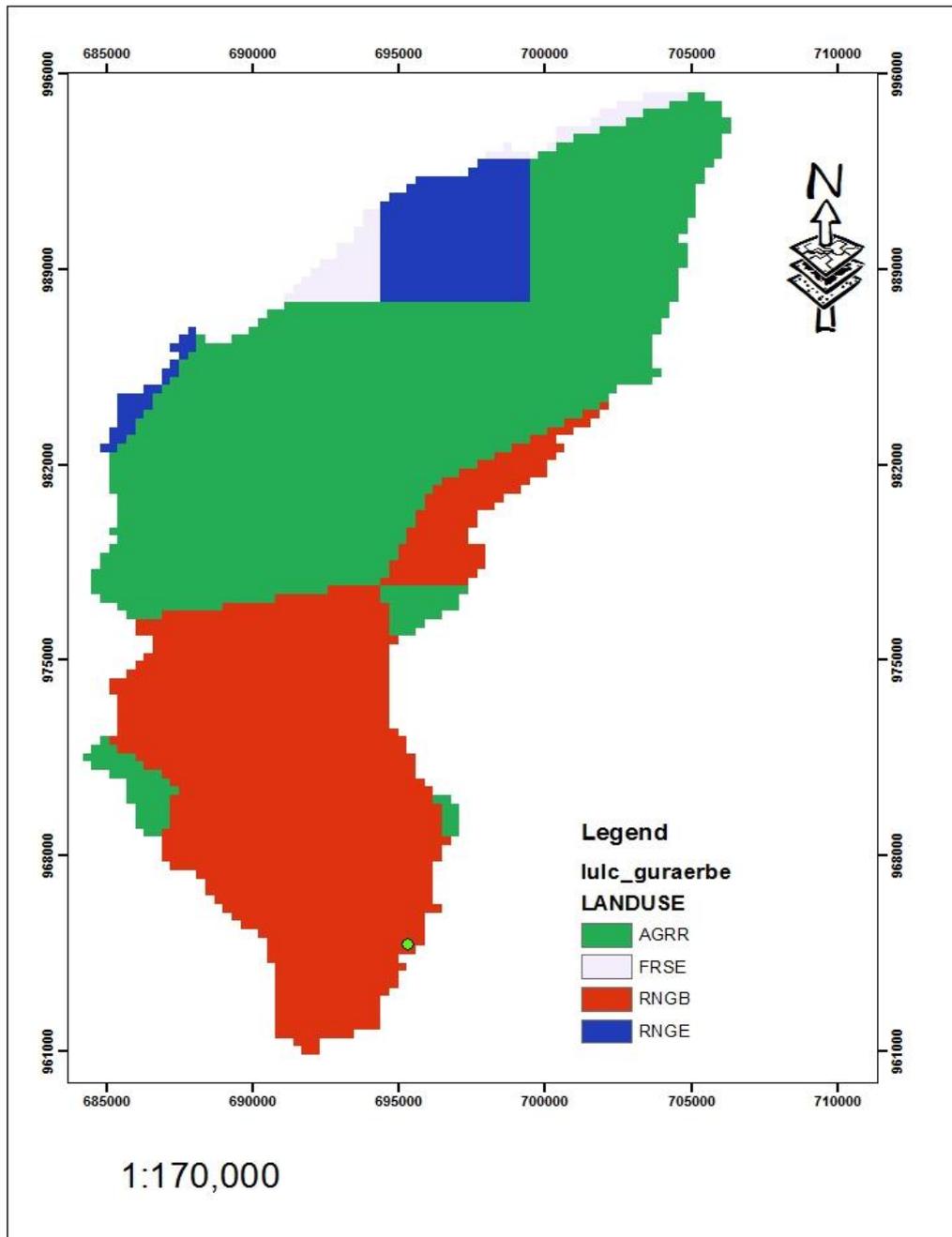


Figure 4-6 : land use/land cover type (Perennial crop) of the middle and upper part of study watershed



Figure 4-7: Land use/land cover type (Perennial crop) of the middle and upper part of study

Figure 4-8: Land Cover map of Gura Erbe Watershed



4.4 TYPE, CAUSE AND EFFECT OF SOIL EROSION

Soil erosion is the detachment of individual soil particles from the soil mass and their transport by erosive agents such as running water and wind. The causing agents of soil erosion could be many, but the type of causes varies with the conditions of a particular area. Both the soil and the agents of erosion determine actual erosion. According to stakeholders, community consultations, and site observation, water erosion in the form of sheet and rill erosion is the dominant form of soil erosion in Gura Erbe Watershed.

Processes of Soil erosion modified by biophysical environment comprising soil, climate, terrain and ground cover and interactions between them. Several factors influence soil erosion; which include rainfall erosivity, soil erodibility; topography, land cover and management.

The most common causes of soil erosion and land degradation in the watershed include but are not limited to-

- Poor farming practices which involve cultivation in steep slopes,
- over grazing of grass lands
- Over cultivation of cropland
- Deforestation

4.4.1 Assessment of Current Soil Loss

The current soil erosion status of study watershed mainly sheet and rill erosion were assessed based on Universal Soil Loss Equation (USLE) that adapted to Ethiopian condition. Most of the models require a lot of input data and a computer analysis. The USLE is selected to be applied as a model for estimating the soil erosion rate because of its suitability, simplicity and availability of information as an input to the model. Furthermore, the USLE is the only soil erosion model adapted to the conditions of Ethiopia by the Soil Conservation Research Project and that is why it is the only suitable model.

The Universal Soil Loss Equation (USLE) is one commonly used erosion model designed to predict the long-time average soil loss in runoff from specific field areas in specified cropping and management systems.

The equation defines the major factors determining soil erosion: $A = R \times K \times L \times S \times C \times P$

Where A = soil loss in tons per acre 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 USLE was developed in particular for USA. Ideally the parameter criteria need to be adapted (through experiment) to local situations. For this reason, the Soil Conservation Research Project (SCRIP, 1996) has developed factors. The different factors adopted are described below:

Soil Erodibility Factor (K): is soil erodibility factor to account for the soil loss rate in t/ha per erosion, index unit plot defined as a plot 22.1 m long and on a 9% slope under a continuous bare cultivated fallow. It ranges from less than 0.1 for the least erodible soils to approaching 1.0 in the worst possible case. K is the soil erodibility factor, which reflects the liability of a soil type.

Ethiopian SCRIP 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 0.3 depending the major soil types of the study area.

Erodibility of soils as defined by Hurni (1988), in the adaptation of the USLE to Ethiopia considers the soil color (Table 4-6) to have relation with erodibility of soils of the study Watershed.

Table 4-6: Erodibility of dominant Soil Types

Soil Type	K Factor
EU LEPTOSOLS	0.1
EUVERTISOLS	0.12
RNLEPTISOLS	0.15
VTLUVSOLS	0.2

Land Cover and Management Factor: C is a combined factor to account for the effects of vegetation cover and crop management techniques. These reduce the rate of soil, so in the worst case, where the soil is bare and no management is being applied, C =1.0. In the ideal case, when there is no loss occurring, C would be zero.

The C- factor, CUSLE, is defined as the ratio of soil loss from land cropped under standard conditions to the corresponding loss from clean-tilled, continuous fallow (c=1.0) (Wischmeier and Smith, 1978). The plant canopy affects erosion by reducing effective rainfall energy of intercepted raindrops. The canopy protection of crops not only depends on the type of vegetation, the stand and the quality of growth but it varies greatly in different months or seasons. The overall erosion reducing effectiveness of a crop depends largely on how much of the erosive rain occurs during those periods when the crop and management practices provide the least protection.

Similarly, the SCRP developed the C-Factor for ranges of land cover and management conditions (Table 4-7).

Table 4-7: C factor for Different Vegetation Classes

Vegetation class	C factor
Dense forest	0.001
Forest	0.01
Degraded forest	0.05
Woodland	0.01
Scrubland	0.02
Grassland	0.01
Dense grass	0.01
Degraded grass	0.05
Open woodland	0.05
Open scrubland	0.06
Cropland/ Wooded cropland	0.15
Cropland, teff as main crop	0.25
cropland, cereals /pulses	0.15
Cropland, wheat/barley	0.15
Crop, sorghum/maize	0.10
Fallow, ploughed	0.06
Fallow, surface crust	0.05
Stone cover 40%	0.08
Stone cover 80%	0.04
Rock outcrop	0.00

Source: Hurni, 1985

Based on this, the value C- factor of the study area shown below in table 4-8.

Table4- 8: C factor for the Study Area

Type of Land Cover	C Factor
Closed Shrub	0.08
Open Grass	0.05
Intensively Cultivated land	0.184
Open Shrub	0.06
Moderately cultivated land	0.184

Support Practice Factor (P): P is physical protection factor, to account for the effects of soil conservation measures. In this context, conservation measures defined as structures or vegetation barriers spaced at intervals on a slope, as distinct from continuous mulches or improved cultural techniques, which come under the management techniques. P is the conservation practice factor, a ratio that compares the soil loss with that from a field with no conservation practice (i.e. ploughing up and down the steepest slope).

The most important supporting practices include contour tillage and planting, strip-cropping on the contour, and terrace systems. Contour tillage and planting provides almost complete protection against erosion from storms of low to moderate intensity, but little or no protection against occasional severe storms that cause extensive break over of contoured rows.

The P- Factor reflects the impact of supporting practices on the erosion rate. The p factor values for a range supporting practices given by the SCRIP to the Ethiopian condition.

The management factor P values range between 0.0-1.0 because of farming practices or conservation measures. The only farming practice increasing erosion (P factor value > 1) instead of reducing it is ploughing in the direction of the slope. Studies conducted (Hurni, 1985) have found different P values for various management practices and land use and cover (table4-9).

Table 4- 9: 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 – wide spacing (20-50 m)	0.7
Contour stone bunds/lines narrow spacing (10 - 15)	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

Depending on the different conservation practice in the study area P factors estimated to be reduced by a factor $P = 0.8$.

The topographic factor (LS): LS is a combined factor to account for the length and steepness of the slope. The longer the slope it is most likely to produce more erosion. The slope map of the watershed produced; showing dominant slope classes as determined from the DEM data using GIS function. Slope class and corresponding in LS factor determined by SCRIP and LS factor for Gura Erbe Watershed are show in table 4-10 and table 4-11 respectively.

Table4- 10 :Slope class and Corresponding in LS factor (SCRIP,1996)

Slope gradient class (%)	Mean LS factor
<2	0.19
2-4	0.38
4-6	0.665
6-8	1.14
8-13	1.9
13-25	3.8
25-40	6.08
40-55	7.98
55-100	10.45
>100	19

Table 4-11: Slope class and Corresponding in LS factor for Gura Erbe Watershed

Slope %	Mean LS factor
0-8	0.47
8-15	1.5
15-25	2.8
25-35	5.4
>35	13.3

The Rainfall Factor: rainfall Erosivity can be defined as the potential ability of the rain to cause erosion, and for a given soil conditions one storm can be compared quantitatively with another and a numerical scale of values of erosivity can be created. The rainfall factor reflects erosivity or rainfall energy factor'. The Ethiopian SCRП developed the R-Factor values based on the annual rainfall amount. The model adapted by Hurni for Ethiopian conditions based on the available mean annual rainfall data (P) where

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

The mean annual rainfall of the Gura Erbe Watershed is 1067 mm. Based on this value the R-factor of the study area was adapted to be **R=469-656**

The above USLE factors combined and multiplied to determine the annual soil losses of the Gura Erbe Watershed. The average annual soil loss and degree of soil erosion in the study watershed is present in table 4-11.

The rate of soil degradation due to soil erosion cannot be assessed with soil loss rates alone. It will be important to include the rate of soil formation or soils loss tolerance as a natural process to build up the soil in situ.

The soil formation rate or tolerable soil loss rate of the study are as indicated by SCRП range from 2-22 tones/ha/year additional, the degree of soil erosion was determined based on the soil formation rate. Hence, as indicated in table 4-11 below areas having an annual soil lose rate above the soil formation rate (>22 tones/ha/year) require immediate intervention. Areas with moderate to high soil loss are mainly intensively and moderately cultivated lands and grasslands on steep topography.

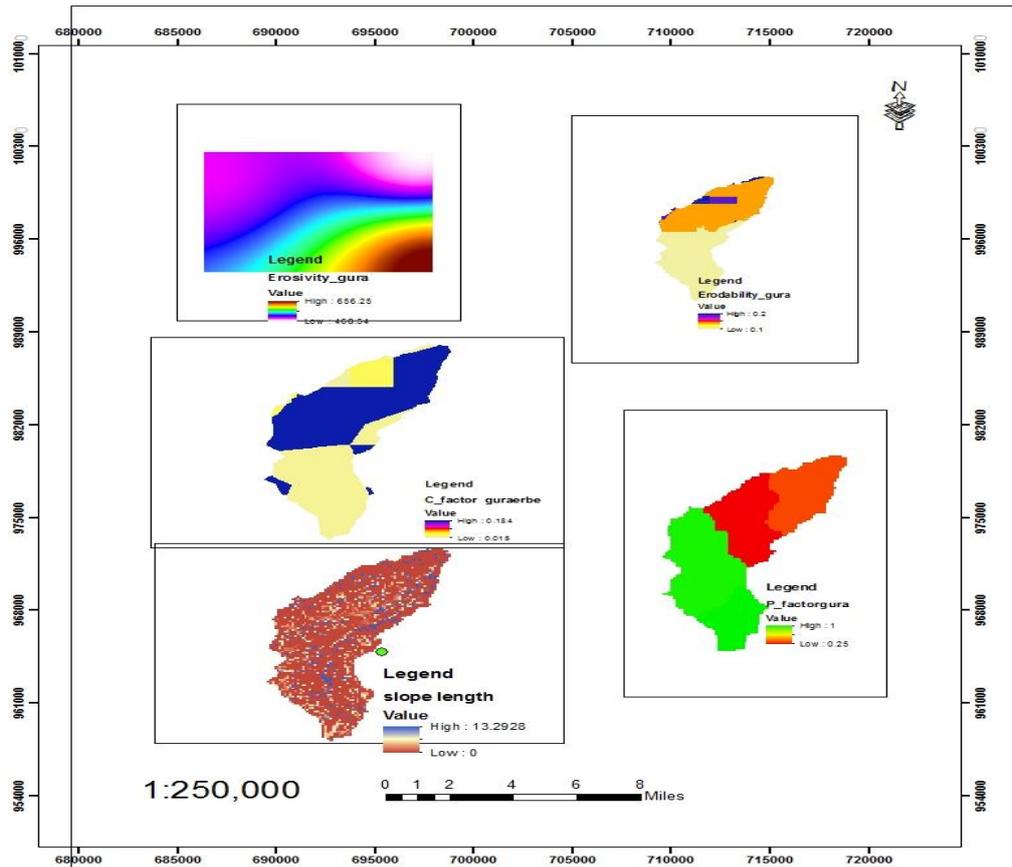


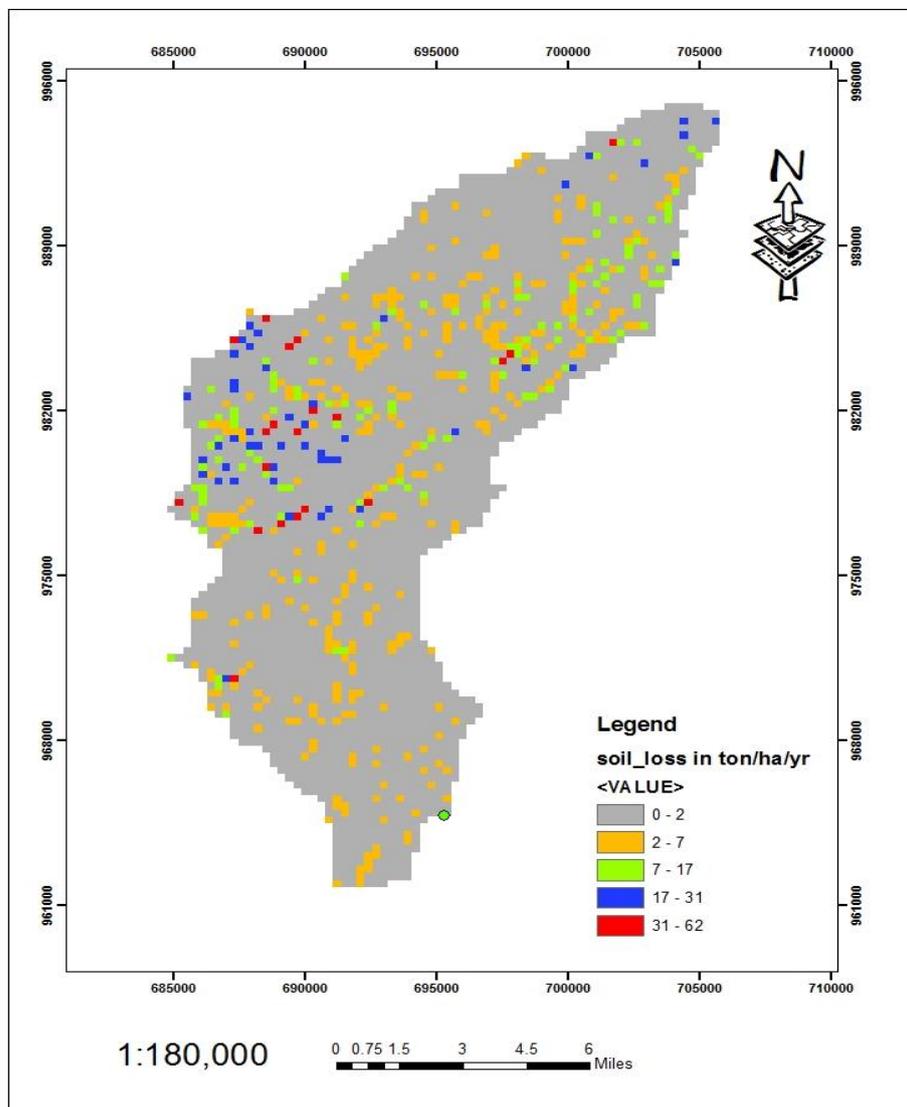
Figure4- 9: USL factors(Erosivity, erodibility, slope Length, C factor and P factor)

Table 4-12: Average annual soil loss (t/ha/yr) and degree of soil erosion in the study Watershed

No.	Slope (%)	Annual maximum soil loss (Ton/ha/Year)	Degree
1	0-8	2	None
2	8-15	7	Slight
3	15-25	17	Moderate
4	25-35	31	Moderate
5	>35	62	High

As indicated in table 4-12, the annual soil loss of the study area reaches up to 62 ton/ha/yr. More of the watershed experiences moderate to high soil loss rate that exceeds the soil formation rate in the area.

Figure 4-10: Soil Loss Status in the Watershed



4.5 NATURAL RESOURCES MANAGEMENT

Despite relatively high population pressure, farmers are practicing perennial crops based agriculture mainly chat & Bananas that provide opportunity to reduce soil loss and erosion hazard. Through biological conservation activities, by planting dual-purpose perennial crops like chat, bananas, fruit trees on steep slope lands the farmers are conserving soil and water resources and reduce flood hazard in the watershed.

5. HYDROLOGIC ANALYSIS AND SEDIMENT YIELD

5.1 SEDIMENT YIELD

The average annual soil loss of the study watershed is about 8.5 ton/ha/yr. From this gross soil loss, portion of the soil loss in the watershed area is deposited in lower slope lands, depressed areas, streams and rivers courses, and obstructed by vegetation cover and other obstacles. Hence, the sediment yield reaching to the out let point may be much below the annual soil losses. Different studies including the Ethiopian highland reclamation study indicated that the sediment reaching to outlet system of a watershed in highland part of Ethiopia estimated to be 10% of the annual soil loss. Other studies also showed that sediment delivery ratio of watersheds vary from 20% to 80% depending on the watersheds characteristics.

For this study, simple empirical formula was used to determine the sediment delivery ratio of the study watershed. The empirical equation is given by:

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

Where, A is the drainage area (ha), SDR is sediment delivery ratio (-)

Table 5-1: Sediment deliver ratio and estimated annual sediment yield at the study watershed outlet

Description	Drainage area (ha)	SDR	Average Annual soil loss(ton /ha/yr)	Estimated Annual sediment yield reaching the Gura Erbe Diversion site ton/ha/yr)
Drainage area of the WS1	7434	0.33	5.5	1.8
Drainage area of the WS2	7983	0.33	6.5	2.15
Drainage area of the WS3	11367	0.31	4.5	1.4
Drainage area of the WS4	4783	0.35	2.5	0.88

The amount of sediment reaching the Gura Erbe Diversion site was calculated using a formula given by: $Q_s = E * SDR$

Where, Q_s = sediment yield (ton/ha/yr); E = estimated soil losses (ton/ha/yr);

As indicted in table 5-1, the sediment delivery ratio is 0.35 that reveals that about 35% of the gross annual soil loss reaches to the Gura Erbe Diversion Site.

5.2 HYDROLOGIC ANALYSIS

Flood estimation methods vary from simple formulas (e.g. rational method) to unit hydrograph methods (e.g. SCS method) to regression analysis methods depending on the data availability.

For any of the methods mentioned above, the basic inputs required could be identified as below:

The precise location of the crossing with geographical coordinates

The catchment area of the drain concerned

Soil type with Hydrologic Soil group

Elevation difference (fall up to the crossing point)

Stream length of the concerned drain

The time of concentration

Land use pattern

The 24-hour storm precipitation corresponding to various return periods.

Hydrologic methods approved by Ethiopian Road Authority (ERA) are rational method (for catchment areas less than 50 hectares), SCS and other unit hydrograph methods for catchment areas greater than 50 hectares and catchment area regression equations. Of these possible hydrologic methods, the Authority recommended the Rational and SCS methods applicable to the whole country.

All the rainfall data over Ethiopia has been analyzed by using statistical techniques by Ethiopian Road Authority to develop the information needed for hydrologic analyses. The analysis results indicate that the country is divided into several hydrological regions (A1, A2, A3, B, C, D1 & D2) which display similar rainfall patterns. Using the statistical analyses, rainfall intensity-duration curves have been developed for commonly used design frequencies. The study watershed falls in region B and the corresponding maximum storm value (mm) in 24 hrs for T years returns period is given below in table 5-2.

Table 5-2 Maximum storm value (mm) in 24 hrs for T years returns period

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

Source: ERA (2001)

The study micro watersheds have an area exceeding 50 ha. Hence, SCS method is employed for flood estimation. The SCS approach is more sophisticated in that it considers also the time distribution of the rainfall, the initial rainfall losses to interception and depression storage, and an infiltration rate that decreases during the course of a storm. With the SCS method, the direct runoff can be calculated for any storm, either real or fabricated, by subtracting infiltration and other losses from the rainfall to obtain the precipitation excess

Accumulated Direct Runoff: The SCS runoff equation a method of estimating direct runoff from 24-hour or 1-day storm rainfall. The equation is:

$$Q = (P - 0.2S)^2 / (P + 0.8S)$$

Where: Q = accumulated direct runoff, mm

P= accumulated rainfall (potential maximum runoff), mm

S =potential maximum retention, mm

$$S \text{ related to CN by: } S = 1000/CN - 10$$

Curve Number (RN) technique, has proven to be a very useful tool for evaluating effects of changes in land use and treatment on surface runoff. The watershed CN is a dimensionless coefficient that reflects watershed cover conditions, hydrologic soil group, land uses, and antecedent moisture conditions. Representative average curve number used for the study watershed derived from the land used and soil type of the study area.

Peak Flood Estimation Methods: SCS method (Madment, 1993) which is based on triangular unit hydrograph is given by:

$$qp = \frac{0.208Ard}{0.5D+0.6tc}$$

Where:

qp = peak discharge (m³/s)

rd = the excess rainfall depth (mm)

A = watershed area (km²)

tc = time of concentration (hr)

D = duration of excess rainfall (hr)

$$tc = (0.87 \times L^3 / H)^{0.385}$$

tc = time of concentration, hr

L = maximum length of flow (km)

H = elevation difference between the most remote and outlet, m

Table 5-3: Summary of watershed parameters

No.	Micro watershed	Area (km ²)	Length (km) (L)	Elevation Max. (m)	Elevation min.(m)	Elev_difference _H (m)	tc(hr)	CN
1	WS1	74.34	7.8	2570	2240	330	16.43	68
2	WS2	79.83	3.9	2130	1850	280	7.5	68
3	WS3	113.67	5.6	2450	2225	225	12.3	68
	WS4	47.83	3.5	2340	2145	205	7.41	68

6. LAND CAPABILITY CLASSIFICATION

6.1 GENERAL

Land capability classification is a means of land classification, used to evaluate the capability of land to support a range of land uses, on a long-term sustainable basis. Geology, soils, slope) plus other factors (eg. climate, erosion hazard, land management practices) which determine how that land can be used without destroying its long-term potential for sustainable agricultural production. It also takes into account limitations that might affect agricultural use, e.g. Stoniness, drainage, salinity or flooding. Land capability assessment is therefore based on the permanent biophysical features of the land (including climate).

The purpose land capability classification is to identify the land capability classes to use for either crops or grazing or Forestry development without further deterioration of the natural resources .It also helps to identify appropriate soil and water conservation measures. The main inputs to land capability classification are land surface characteristics including slope, topsoil depth, past soil erosion, top soil texture, drainage condition, infiltration and rockiness /stoniness

There are different types of land capability classification methods such as land treatment based classification, land suitability classification and soil and water conservation classification methods. In Ethiopia widely used and adopted to the Ethiopian conditions is the soil conservation requirement classification (SCRC) method. This classification method was developed and adapted by Escobedo, and which is modified to suit the Ethiopia condition for small and large watersheds.

The SCRC system of classification can be used as part of watershed management study helps as a tool to know land abuse, and enable to quickly read landscapes and identify solutions. The classification system recognizes eight classes of land units – class I (best) to class VIII (worst). The higher the class is the lower the capability for agriculture, and the higher the risk of erosion.

The land capability classification is based the former Community Forestry and Soil Conservation Department of the Ministry of Agriculture (Escobedo, 1988) and Watershed management guideline (Escobedo, 1990).

This classification system recognizes eight classes of land units class I (best) to class VIII (worst). The higher the class the lower the potential (capability) for agriculture, and the higher the risk of soil erosion. In general, land units of class I to class IV are suitable for annual crops.

Class V is a wetland suitable only for temporary grazing. Class VI is a land suitable for perennial crops or grazing. Class VII is a land suitable for forestry. A land not suited for agriculture falls under class VIII (It could be used for wildlife, watershed protection).

The land capability classes mapped as Roman numbers (I-VIII), suffixed by letters of subclasses/limitation, example E-erosion and runoff, W-excess water, D-root zone limitations etc. as IIE, IIIW, IVD etc. The capability units designated by ordinary numerals placed as subscripts to the subclasses in the capability notation, example IIE2, IIIW0-1, IVD1-3 etc. The capability unit indicated by ordinary number shows the severity of the specific limiting factors on the capability of land.). The most limiting factors that determine the classes in the study area are slope (L), past erosion (E) and drainage conditions (W). The conversion table for land capability classes, suffixed, and land capability units are shown table in 7-4 below.

Detail description eight land capability Classes (I to VIII) for soil conservation requirements are presented below.

The degree of hazard or limitations increases from class I to VIII.

Class I: land has few limitations that restrict their use. Intensive cropping can be used and soil conservations are not necessarily other than preventive ones to maintain a good vegetation cover.

Class II: land has some limitations that reduce the choice of plants or require moderate conservation practices. Limiting factors are: gentle slope (< 8%), moderate erosion hazards, moderate soil depth, less than ideal soil structure and workability, slight to moderate alkali or saline condition, stoniness (<3 %), somewhat restricted drainage and no water logging.

Class III: land has severe limitations that restrict the choice of plants or require special conservation practices or both. Limitations in the use of soils are moderately steep slope, high erosion hazards, very slow water permeability, moderate depth and restricted root zone, low water holding capacity, low fertility.

Class IV: land can be used for cultivation but there are very severe limitations. These are steep slopes, severe erosion susceptibility, severe past erosion, shallow soils, low water holding capacity, poor drainage, severe alkali or salinity.

Class V: Lands are limited in their safe use by factors other than erosion hazards. These limitations are subject to frequent overflow, growing season too short for crop plants, stony or rocky soils and ponded area where drainage is not feasible.

Class VI: land has severe limitations, which restrict their use to grazing, woodland or wildlife. The physical limitations are the same as those for class V but severity of limitation are more.

Class VII: land has very severe limitations, which limits their use to grazing, woodland or wildlife. The physical limitations are the same as for VI except that they are too severe for improvement.

Class VIII: land should not be used for any kind of production having severely eroded potential and/or other limitations. These include swamps, river washed plains, sand dunes and barren mountains. They should be used only for recreation, wildlife, water supply structures or aesthetic purposes.

The main producers followed in land capability classification are:

- watershed of the study area was divided based on land cover, slope class and major soil type
- Physical characteristic including slope, the soils especially soil depth, infiltration rate, drainage, top soil texture and stoniness were determined
- The land capability class units were identified using the Escobedo land capability classification shown in table 6-3 and the conversion table below in table 6-4.

6.1.1 Land capability Classification Result

The land capacity classification result of the study area is presented in table 6-1. The result indicates that the study area falls under five land capability classes such as I, II, III, IV, VI. Land classified in the same land class unit can vary in their limiting factors. The result of land capability or soil conservation requirement classification shows that the major limiting factors of the land use in the watershed are mainly soil erosion and slope.

According to this classification, the area is suitable for annual crop production, development of perennial crops, grazing land and fodder development. Integration of appropriate watershed management is important to almost in all slope ranges to reduce erosion and sustain the productivity of the area.

Table 6-1 : Land resource data and Land Capability classification results

No.	Micro watershed	Area Coverage (ha)	Slope (%)	Soil Depth	Past erosion (E)	Texture (T)	Water logging (W)	Infiltration (I)	Surface stoniness (S)	LCU	SCRC
			L	(D)					S		
1	WS1	7434	3-8	D1	E0	T5-T6	W0	I0	S0	IIL2	II
			8-15	D1	E1	T5-T6	W0	I0	S0	IIIL3E1	III
			15-30	D1	E2	T5-T6	W0	I0	S0	IVL4E2	IV
			>30	D2	E3	T5-T6	W0	I0	S0	VIL5 E3	VI
2	WS2	7983	3-8	D1	E0	T5-T6	W0	I0	S0	IIL2	II
			8-15	D1	E1	T5-T6	W0	I0	S0	IIIL3E1	III
			15-30	D1	E2	T5-T6	W0	I0	S0	IVL4E2	IV
			>30	D2	E3	T5-T6	W0	I0	S0	VIL5 E3	VI
3	WS3	11367	3-8	D1	E0	T5-T6	W0	I0	S0	IIL2	II
			8-15	D1	E1	T5-T6	W0	I0	S0	IIIL3E1	III
			15-30	D1	E2	T5-T6	W0	I0	S0	IVL4E2	IV
			>30	D2	E3	T5-T6	W0	I0	S0	VIL5 E3	VI
4	WS4	4783	3-8	D1	E0	T5-T6	W0	I0	S0	IIL2	II
			8-15	D1	E1	T5-T6	W0	I0	S0	IIIL3E1	III
			15-30	D1	E2	T5-T6	W0	I0	S0	IVL4E2	IV
			>30	D2	E3	T5-T6	W0	I0	S0	VIL5 E3	VI

Limiting factors: E= erosion, L= slope, D= soil depth, W= water logging, T= soil texture, S=surface stoniness

The results of the land capability or soil conservation requirement classification show that the major limiting factors of the land use in the watershed are slope, and soil erosion, irrespective of slope category. Table 6-1 shows that 53 % of the watershed area is grouped into class IV and VI. Class VI should not be used for agricultural purposes without any soil and water conservation interventions. In general, the land capability classification result shows that only 6.5% the land can be used without any treatment with soil and water conservation or management interventions.

Table 6-2: Description of land capability units(LCU)

LCU	Description
I	Land capability class one with no limiting factor
III	Land capability class IV with slope limiting factor
IIIL3E1	Land capability class IIILE with slope & soil erosion limiting factor
IVL4E2	Land capability class IVL with slope limiting factor
VIL5E3	Land capability class VILE with slope & soil erosion limiting factor

Table 6-3: The Escobedo Land capability classification table used as guide for land capability classification

No.	Limiting factor Codes							Soil conservation Requirement class	
	Slope (L)	Soil depth (D)	Past erosion (E)	Top soil texture (T)	Water logging (W)	Infiltration (I)	Surface stoniness (S)		
1	L2	D1-D2	E0	T3-T6	W0	I0	S0-S1	II	Land suitable for perennial crops grazing with special management and Land suitable for forestry Swap areas, river beds
2	L3	D1-D2	E0-E1	T3-T7	W0-1	I0-I1	S0-S2	III	
3	L4	D1-D3	E0-E2	T2-T7	W0-W2	I0-I2	S0-S2	IV	
4	L1 -L4	D1-D4				I0-I2			
5	L5	D1-D3	E0-E2	T2-T7	W0-W2	I0-I2	S0-S2	VI	
6		D1-D4	E0-E3	T2-T7	W0-W2	I0-I2	S0-S2	VII	
7		D1-D5	E0-E4	T1-T7	W0-W2	I0-I2	S0-S2	VIII	
8		D1-D4	E0-E4	T1-T7	W0-W3	I0-I2	S0-S2	V	

Table 6-4: The conversion table used for land capability classes, suffixed, and land capability units

Slope class (L)		Soil depth (D)		Past erosion (E)		Texture(T)		Water logging(W)		Infiltration(I)		Stoniness/Rockiness (S)	
0-3 %	1	>150 cm	1	Nil	0	Sand	1	Well drained	0	Very permeable	0	<15 %	0
3-8%	2	100-150	2	Slight	1	Sand	2	Imperfectly	1	Slowly	1	15-30 %	1

		cm				loam		drained		permeable				
8-15%	3	50-100 cm	3	Moderate	2	Loam	3	Poorly drained	2	Impermeable	2	30-50 %	2	
15- 30%	4	25-50 cm	4	Severe	3	Silt loam	4	Very poorly drained	3		2	50-85 %	3	
>30	5	<25 cm	5	Very severe	4	Clay loam	5				Very poorly drained	3	2	>85 %
						Clay, silt clay	6							
						Heavy clay	7							

7. SOCIO-ECONOMIC CONDITIONS

Socio-economic information is vital for identification of major potentials and problems related to social and economic. It helps to prioritize the main problems of the community in proposing acceptable and technically sound watershed management interventions.

The Socio-Economic situations of the study area were collected from the respective Woreda Offices and Kebeles with predefined format, discussion with experts and community members.

7.1 FARMING SYSTEM

Farming system is valuable as it offers an opportunity to devise a rational approach to accelerate the agricultural development through optimized and sustainable use of the natural resources in any case that does not harm the natural environment.

Perennial crops production such as chat, bananas, coffee, avocado and banana are the most significant enterprise that supports household livelihood and the fundamental economic base of the community. Similarly, maize, haricot bean, potato, kale, tomato and pepper are annual crops growing for different purposes.

Chat-Bananas based horticultural farming system: the farming system characterized by mixed farming system lion share of the cropping pattern is undertaken by Chat plantation. Bananas and coffee are second important crops in this farming system where they accompanied with vegetables and fruit tree crops.

Bananas are a major staple crop in the project area, while other annual perennial crops are growing for income generating purpose. This farming system has the much-diversified types of crops because of suitable agro-ecosystem for many potential crops. The major crops growing in this farming system are chat, bananas, coffee, maize, haricot bean, potato, sweet potato, kale, banana, avocado, papaya, mango, and guava.

Land preparation activities are undertaken by hoe cultivation and to some extent draught power is used for first ploughing. All other activities are manually managed using the family and extra labor as required. The perennial crops bananas, coffee, avocado, mango, and papaya are mostly planted near to the homesteads.

In this farming system livestock sector has limited contribution to livelihood of the people because of forage resource scarcity. However, each household would have a minimum number of cattle to meet family requirement. As part of the household land use system each household has own grazing plots where the cattle are kept during daytime for stall-feeding.

In addition, following fieldwork and discussions with wereda staff, it was indicated that on-farm forestry and agro-forestry plantations had been promoted.

7.2 NATURAL RESOURCES MANAGEMENT

Despite relatively high population pressure, farmers are practicing perennial crops based agriculture mainly chat & Bananas that provide opportunity to reduce soil loss and erosion hazard. Through biological conservation activities, by planting dual-purpose perennial crops like chat, bananas, fruit trees on steep slope lands the farmers are conserving soil and water resources and reduce flood hazard in the watershed.

8. MAJOR WATERSHED PROBLEMS, POTENTIALS AND OPPORTUNITIES

The biophysical and socio-economic features of the study area have been analyzed as part of the system. Then, the major problems, potentials and opportunities have been traced from the analysis of biophysical and socioeconomic conditions.

8.1 WATERSHED PROBLEMS

Increased vulnerability to soil erosion hazard on steep slope, low livestock production and productivity moreover, deforestation, low crop diversity and productivity and inadequate alternative income sources, increased fuel wood and construction wood demand, inadequate fuel wood supply are some of the watershed increased fuel wood and construction wood demand, inadequate fuel wood supply are some of the major problems and discussed in the following section.

8.1.1 Soil Erosion

Physical degradation of soil is most spectacular in the form of sheet and rill erosion. It is evident in steep slopes the study area that are kept under cultivation and in many areas of grazing land. The natural factors like seasonally abundant rainfall, erodible nature of the soil characteristics and steep and undulating topography are factors a contributing to this problem .

8.1.2 Low Livestock Production and Overgrazing

The main challenge in livestock productivity in this study area is inadequate supply of livestock feed sources in quantity and quality. The rate of stocking on grazing land is high. As the result, shortage of grazing land is a serious problem in the area particularly in the dry seasons. Moreover, increased livestock density that leads to overgrazing and trampling effects, which aggravate formation of micro-gullies, has been one of the main causes of land degradation of the watershed. Despite stall feeding experience in the watershed, mainly communal land exposed to overgrazing and resource degradation that aggravate soil erosion.

Therefore, the most appropriate management of livestock husbandry and grazing land management system need to be implemented that can be adequately sustained with available feed and improved forage development strategies should be improved in the faming system. Appropriate management of livestock will improve the productivity in addition to controlling

unnecessary pressures on natural resources that may also reduce degradation on the soil and forest resources.

Therefore, to reverse this situation proper management of grazing lands and increasing the availability of need to be considered to improve the productivity of the livestock on sustainable basis with little and no jeopardize on scarce natural resources.

8.1.3 Deforestation

Deforestation is loss of vegetation resources, which is both cause, and consequences of soil erosion. It leads to increased runoff in a short duration and worsening in ground and surface water resources. Dense forests, bush and moderate forest cover of the study watershed, which shows the increasing trend of deforestation rate.

Weak implementation of land use policy and proclamations, uncontrolled cutting of trees and shrubs for various purposes, notably firewood, charcoal, construction and expansion of cultivation due to rapid population growth and decrease in farmland holding are the major causes of deforestation in study watershed area. The pictures on the following pages illustrate deforestation in the area and charcoal production.



Figure 8-1: illustrate deforestation in the area and charcoal production

8.2 EXISTING OPPORTUNITIES AND POTENTIALS

The secondary information and farmers' explanation on watershed management, opportunities in terms of biophysical resources and socio-economic conditions for development are identified. The major opportunities of biophysical resources include favorable agro ecology, availability land and water resource and existing experience perennial crop cultivation. Whereas the socio-economic conditions opportunities include availability of able-bodied labor force, availability of institution and policy background to implement watershed management, availability of rich farming system and Willingness, traditional knowledge and local experience in land conservation the study identified the following opportunities that will support and achieve the development of the watershed in the future.

8.2.1 Bio-physical opportunities

- Suitable agro-ecological conditions for growing various high land fruit and multi-purpose trees and shrubs that could be used as sources of income and animal feed, soil fertility maintenance and ecosystem conservation
- availability of natural pasture land to carry out improved pasture development practices;
- Relatively better forest cover that can be enhanced through continuous awareness of the community and enrichment plantation;
- Availability of land and water resources to establish nurseries in the area access seeds to develop nursery;
- Availability of water resources for development of small scale irrigation agriculture;

8.2.2 Socioeconomic Opportunities

- The existence of human labour and a community culture to work together to carry out watershed development interventions through community participation are vital to the implementation of any watershed development plan.
- The availability of an institution such as the community watershed team, planning team or development committee
- The existence of awareness about protecting land from erosion, degradation and flooding
- Productive work labor availability for intervention

- Community willingness to participate in watershed conservation tasks
- Fertile policy background to implement watershed conservation measures
- Institutional capacity from top to grass root levels to engage in conservation development
- Availability of rich farming system promoting biological conservation to be easily adopt in the system
- Relatively good climatic condition for perennial crops, fruits and for water harvesting
- Willingness, traditional knowledge

8.2.3 Development Potentials

The watershed development potentials are noted from the suggestion forwarded by technical staff of wereda bureau of agriculture and natural resource; key informants and focus group discussion participants. The potential of the watershed in terms of watershed management are highlighted below:

- The existence of favorable climate to grow various crops (field crops, fruits, vegetables)
- Rainfall availability for water harvesting at household and community level.
- The existence of the institutional set up by the government
- The existence of traditional soil and water conservation practices
- Traditional runoff diversion for irrigation
- Planting perennial crop such as chat, bananas ,coffee and fruits
- Compost-making using manure around homestead.

9. WATERSHED DEVELOPMENT INTERVENTIONS

9.1 SELECTION AND COMPONENTS OF WATERSHED INTERVENTIONS

The recommended watershed management interventions identified based on the information acquired from the study, the finding and analysis of biophysical and socio economic problems, constraints, opportunities and potentials.

The following specific factors considered in the selection of watershed management recommendations.

- Existing practices and experiences of the community
- agro-ecologic condition of the area
- Potentials and constraints of the watershed
- Proven capability of the chosen interventions to control soil erosion and avoid land degradation
- Integration potentials of different interventions' technologies
- Feasibility of the technologies and their application and adaptation in the land use and farming system
- The overall impact expected in reducing flood and sediment deposition on the downstream infrastructures.

Accordingly, a broad range of possible interventions and techniques are recommended. The results of the discussion and land capability classification analysis results are incorporated to have identified diversified and integrated watershed management interventions. Indigenous knowledge of farmers, professional experiences and views are also well incorporated in the selection of specific interventions.

The Major project components include:

- Agronomic & biological Soil and Water Conservation Measures
- Physical Soil and Water Conservation Measures
- Livestock Development
- Alternative Income generating schemes / Promotion of off-farm activities
- Alternative Energy technology
- Environmental Education in Schools
- Local Capacity Building

Table 9-1: Summary of recommended development options according to LCC of Gura Erbe watershed

LCU	Major limiting factor	Cultivated land	Grass land	Forest land ,Wood land	Shrub land
IIL3E1	slope (8-15%) & slight erosion	alley cropping	convert to cultivated land	same as	
		combination of grass strip and graded soil or stone bunds	grassland improvement	above + strip plantation following the contours	same as above + enrichment plantation
		water ways & cutoff drain	convert to agrosilvipasture land		
IVL4E2	Slope (15-30 %) & moderate erosion	combination of grass strips and graded bunds	convert to cultivated land	same as options for class I + fuel wood plantations + encouraging ground vegetation cover	same as options for class II + fuel wood plantations + encouraging ground vegetation cover
		alley cropping	convert to agro silvi pasture land		
		bench terraces			
		If moderate past erosion, apply cutoff drain & waterways.	cutoff drains and water ways		
		convert to grassland or forest land	a. grassland improvement	fuel wood plantation + micro basins	
VIL5 E3	slope >30 & Severe erosion	establish perennial crops	control grazing		
		graded bunds		fuel wood plantation + micro basins	fuel wood plantation + micro basins
		If moderate past erosion, apply cutoff drain & waterways.	convert in silvipasture land		

9.2 AGRONOMIC & BIOLOGICAL SOIL AND WATER CONSERVATION MEASURES

9.2.1 Contour Cultivation

Contour cultivation and contour planting, which is non-monetary inputs, are basic agronomical practices, which should be adopted on slope lands. Cultivation operations are done across the slope, i.e. by keeping them on contour or nearly so. The contour furrows so created would form a multitude of mini barriers across the flows path of the runoff, which improves vastly the detention storage in situ. This will in turn increase the opportunity time and hence the infiltration of rainwater in to the soil profile whereby quantity velocity of runoff and hence its erosive potential greatly reduced. Further, when cultivation is done on the contour instead of up and down cultivation, much less power is required to be exerted by men and animals. Thus, it can be seen that contour cultivation remains the most effective on the moderate slopes of 2 to 7% whereas both on flat or steep the effectiveness is relatively less.

9.2.2 Crop Rotation

Crop rotation means growing different crops in the same field from one year to the next and a traditional crop rotation is seen to be practiced in the watershed area. It maintains and restores soil fertility and controls the buildup of pests. Cereals in the first season \Rightarrow followed by a legume in the second season \Rightarrow , then oil or a root crop in the third season \Rightarrow they can then plant cereals again in the following season. Leguminous crops are especially important in rotations because they fix nitrogen and restore soil fertility. Crop rotation can be used in all agro-ecological zones of the watershed where farming is practiced, and on all soil types.

9.2.3 Compost and manure

Compost is fertilizer made from leaves, weeds, manure, household waste and other organic materials. It supplies a wide variety of plant nutrients. It also creates a favorable environment for soil microorganisms.

Compost and manure is valuable natural fertilizer that contains readily available plant nutrients. It improves the water-holding capacity of the soil.

Manure consists of animal dung and urine. It is the best form of organic manure. Using manure as fertilizer encourages the growth of beneficial microorganisms, worms and other soil organisms. It recycles nutrients and preserves soil fertility. It benefits the environment by using waste in a productive way. It is available on the farm.

Farmers in the study area use animal manure for bananas. Therefore, strengthening and promoting the existing practice through training and support to the community, as a project is very important.

9.2.4 Agro-forestry

Agro-forestry defined as a sustainable land management system that increases the yield of land, combines the production of crops (including trees) and wood plants or both simultaneously or sequentially on the same unit of land and applies management practices that are compatible with cultural practices of the local community. Some of the agro-forestry practices include alley cropping, intercropping, multi-story cropping, relay cropping, sequential cropping and strip cropping.

9.2.5 Grass Strips

A grass strip is planted along the contour on cultivated land to reduce the amount of water flowing down the slope and to retain soil. Usually, the strips will be laid out at 1m vertical interval; widths of strips could vary (0.5-1.5m) based on density of plants in the strip. Grass strips used alone on slopes 3 to 8 percent and integrated with physical measures alternatively in 8 to 15 percent slopes.

9.3 PHYSICAL SOIL AND WATER CONSERVATION MEASURES

Physical SWC measures are effective for retarding runoff velocity, and consequently store sediment that is carried by runoff and retain water in to the soils or safely dispose excess runoff water without affecting the downstream. There are various physical measures can be applied on different land uses types. The following Physical SWC measures are proposed to the study area.

Soil Bund: Soil bunds are earth banks thrown across the slope to act as a barrier to runoff, to form a water storage area on their upslope side and break up a slope into segments shorter in length than is required to generate overland flow. They are suitable on slopes between 3 to 15% on cultivated lands.

The bunds could be stone-faced in areas with high stoniness and stable soils. Planting of mixture of grasses, legumes and other multi-purpose agro-forestry species should be integrated with such measures .soil bunds are perfectly adequate as long as they are maintained.

The Gura Erbe watershed area receives less rainfall and characterized by steep slopes thus, level bunds is recommended.

Table 9-2: Spacing between bunds

Slope (%)	Spacing (m)		
	Sandy soils (easily erodible)	Silt loam soils (moderately erodible)	Clay soils (less erodible)
3-8	15-40	20-50	25-60
9-20	8-14	8-19	10-24
21-40	4-7	5-7	5-10
41-50	3-4	3-4.5	4.6-5.8

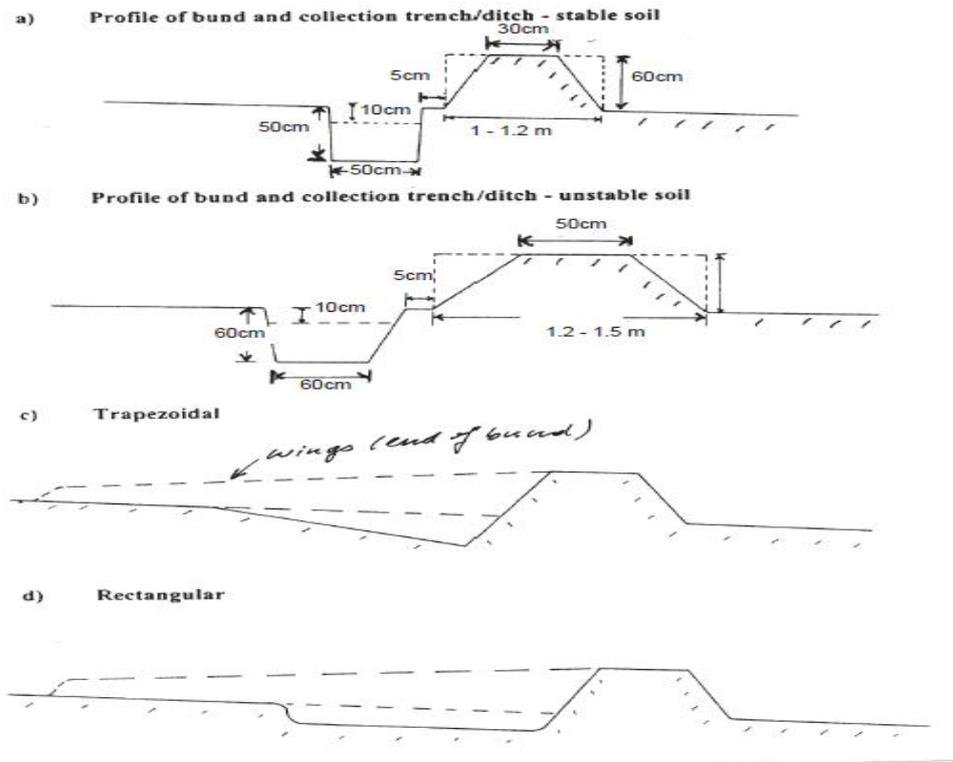


Figure 9-1: Design of Soil Bund

Source: MOA (2005)

Bench Terraces: A bench terrace is a level (or almost level) step built on a slope. It is leveling land to reduce soil erosion. Benches convert hillsides into level land that is suitable for planting crops. Grass and legumes can be planted on the terrace walls and used to feed animals.

Bench terraces take a lot of work to build and maintain. Terraces are not suitable on shallow soils because of the large amount of earth that must be moved. Bench terraces are used in all agro-ecological zones where agriculture is practiced. All soil types, but the soils must be deep and slopes up to 50%.

The vertical distance between the base of one bench terrace wall and the base of the next, one down the slope should be 2.5 times the depth of the soil. For example, if the depth of the soil is 1m, the base of one wall should be 2.5 m above the base of the next wall down the slope.

Table 9-3: Width of cultivated land on bench terraces at different

Slope (%)	Soil depth (cm)					
	25	50	75	100	125	150
20	3 m	6 m	8 m	11 m	14 m	17 m
30	2 m	4 m	5 m	7 m	9 m	11 m
40	1 m	3 m	3 m	5 m	6 m	8 m
50	1 m	2 m	3 m	4 m	5 m	7 m

Table 9-4: Summary of technical standards, layout & vertical intervals for major physical conservation measure

No.	Physical Conservation	Technical standards					Layout and vertical intervals (VI) (m)			Work norm	Remark
		Height (cm)	Base width (m)	Top width (cm)	Ties (m)	Length (m)	Slope (%)				
							3-8%	8-15%	15-20%		
1	Level soil bund	60	1-1.2	30	3-6 m interval along channel	30-60	1-1.5	1-2	1.5-2.5	150 PDs/Km	
2	Graded soil bund	60	1-1.2 (stable soil), 1.2-1.5 (unstable soil)	Top width: 30 cm (stable soil) & 50 cm (unstable)			1-1.5	1-2			For Slope 15-30 % VI = 1.5-2.5 m
3	Bench Terraces		2-5	.						500 PDs/Km	for cultivation by hand dug (2-5m) and greater for animal driven cultivation

Source: MOA (2005)

9.4 LIVESTOCK DEVELOPMENT

Livestock play a number of vital roles in the rural and national economies. For instance, the broad function of livestock in the rural communities includes traditional- power, manure, fuel woods, food, and a coping strategy for emergencies. However, there is livestock feed shortage for livestock in the study area. Thus, improving the livestock production through increasing the availability of fodder and improving the grazing land management system need to be an integral part of the watershed management plan.

The followings are some of the options proposed for livestock production improvements part of watershed management.

- Pastureland improvement and management
- Establishment of fodder seed multiplication site
- Promoting back yard forage production systems

9.5 ALTERNATIVE INCOME GENERATING SCHEMES

Increasing diversification of income sources is highly necessary to be considered to reduce land degradation as well as to increase income of the watershed inhabitant's .This involves Improvement of farmers' living standards mainly through the promotion of non agricultural income generating activities including:-

- provision of opportunities for income generation through introduction of fruit trees including highland apple
- Vegetable and fruit farming
- poultry
- Production of energy saving stove

9.6 ALTERNATIVE ENERGY TECHNOLOGY

Unless alternative energy sources are sought and complimented, the conventional sources of the present supply of fuel wood is not sustainable. Stoves are the main factor contributing to degradation of forest resources and the prevailed shortage of fuel wood. In addition to this, the rural people use crop residues and cow dung as the main source of energy that might rather be used to improve the fertility of soils. The cooking stove usually also open fire, which consumes large amount of biomass fuel.

To reduce the above problem, promotion of fuel-efficient stove and alternative rural energy sources is highly essential. In light of this, energy saving stove and solar lantern technologies are proposed as part of this watershed management.

9.7 ENERGY SAVING STOVE

Promotion of fuel-efficient stoves could reduce consumption of fuel *wood* compared to open fire system. In this regard, Mirt stove and other energy saving stoves are appropriate for the context of the area. This could reduce consumption of fuel wood by 50% compared to the open fire stoves and thereby significantly reduces pressures on natural resources. This also helps to reduce workloads on women that might rather be devote in collection of firewood and protects fire hazards on women and children.

Therefore, under this strategy, it is planned for all HHs inhabiting in the two target Woredas will have access to energy saving stove. This is could be provided through a cost sharing mechanism, with 80% from the project and 20% from the users. The purpose of the cost sharing system is to increase sense of ownership on the technology, to reach large number of HHs and support sustainable supplies in the locality.

9.7.1 Solar lantern

A solar lantern is a lighting system consisting of a lamp, battery and electronics, all placed in a suitable housing and made of metal, plastic or fiberglass. This time different types of solar lanterns are available in the market, which can deliver enough electricity in an eight-hour charge to light up an entire room for 6-12 hours. The solar lanterns are found in some Woreda markets. Despite the high price and limited availability, most farmers were stated their interested to this technology.

Thus, this technology shall be promoted in the study area as means of compacting the problem of electricity in areas where did not connected to the national grid. .

9.7.2 Homestead tree plantation

Homestead tree plantation, forest development in the closure area and wood lot plantations and road and farm boundary plantations are recommended in addition of the existing once as alternative energy sources in the watershed

9.8 FAMILY PLANNING

Family planning can be considered as one of the interventions of watershed management as uncontrolled growth of human population could be contributing to deterioration of the natural resources. The family planning helps to control population growth in compatible with the existing resources and the economic growth and thereby reduces economic burden on the poor households and reduce pressures on natural resources.

In light of this, a total of women in reproductive age groups shall have access to family planning services including education and supply of family planning medicines. The FP service should be provided through health institutions via the health extension promotion workers based at KA levels in both regions. The family planning medicines and facilitates the distribution of the medicines to users accordingly. FP education will be given to the communities through already ongoing health extension system.

9.9 ENVIRONMENTAL EDUCATION IN SCHOOLS

Schools are the best model in disseminating better attitudes, knowledge and skills to their family and the community at large. Schoolchildren possibly will educate their family and surrounding community through conducting environmental education sessions, staging role play dramas and demonstrating in school compounds related to conservation of the natural resources.

Therefore, environmental education in schools is another activity proposed this watershed management. To this end, school based environmental clubs will be established in primary schools found in the watershed area. To realize this activity, the project will support the clubs in the provision of audiovisual, and finance to facilitate environmental education sessions in schools and surrounding community. The financial and material assistances should be provided to schools through the respective institution. Thus, secondary schools found in the study area will be the target for this activity.

9.10 LOCAL CAPACITY BUILDING

Capacity building for farmers, extension staffs, and experts is one of the main important strategies proposed in this watershed management study. Continuous trainings on different disciplines like SWC, forestry, fruit production, apiculture in general in participatory watershed management etc should be given to further make farmer , extension staffs, and experts self-capable in all their actions and attempts that promote them to self-sufficient in all needs and sustain by themselves. . Furthermore, construction tools required for the implementation of the planned activities like pickaxe, shovel, crowbars, etc should be provided to the communities' members to facilitate the implementation of the planned activities.

The government staffs with their role of providing intense technical advice to farmers need to have adequate knowledge on principles and art of watershed management. Although they have started in implementing the same activities, there are still limitations on the implementation principles, strategies, and techniques of watershed management.

The possible interventions planned under the capacity-building component include but not limited to-

- Training on watershed management principles and techniques to experts, development agents and supervisors;
- Furnishing with tools and surveying equipment;
- Provision of motor bike and field vehicles;

10. WATERSHED DEVELOPMENT PLAN AND BUDGET ESTIMATES

10.1 GENERAL

Demand driven approach is to be practiced in which the beneficiary communities shall submit their request for assistance and willing to contribute their free labour required for the implementation of the activities. Promotional work will be done DAs and community leaders during the planning phase. Implementation process then starts by providing again a short briefing to the beneficiaries, about the components objectives, intervention, activities and their participation during the implementation process, in general assembly of the communities. Furthermore, Plan of implementation of watershed management intervention should also take into consideration the farming calendar of the farmers.

Estimation of the project cost, required inputs and implementation schedule are indicated below. It is recommended that detailed implementation plan have to be worked out during actual annual action plan preparation at project level.

10.2 HOT SPOT AREAS, PRIORITIZATION OF INTERVENTIONS AND DEVELOPMENT PLAN

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

The map is essential to identify critical areas along with the proposed intervention measures, the extent of the areas and the volume of inputs required. In order to locate on the ground where the various soil and water conservation measures and other interventions are to build watershed map preparation is essential.

We assessed the watershed characteristics and identified a hot spot areas based on the following but not limited to; Areas with land capability classes V- VIII, 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. As discussed in the above section we presented in Development map figure 10-1 below.

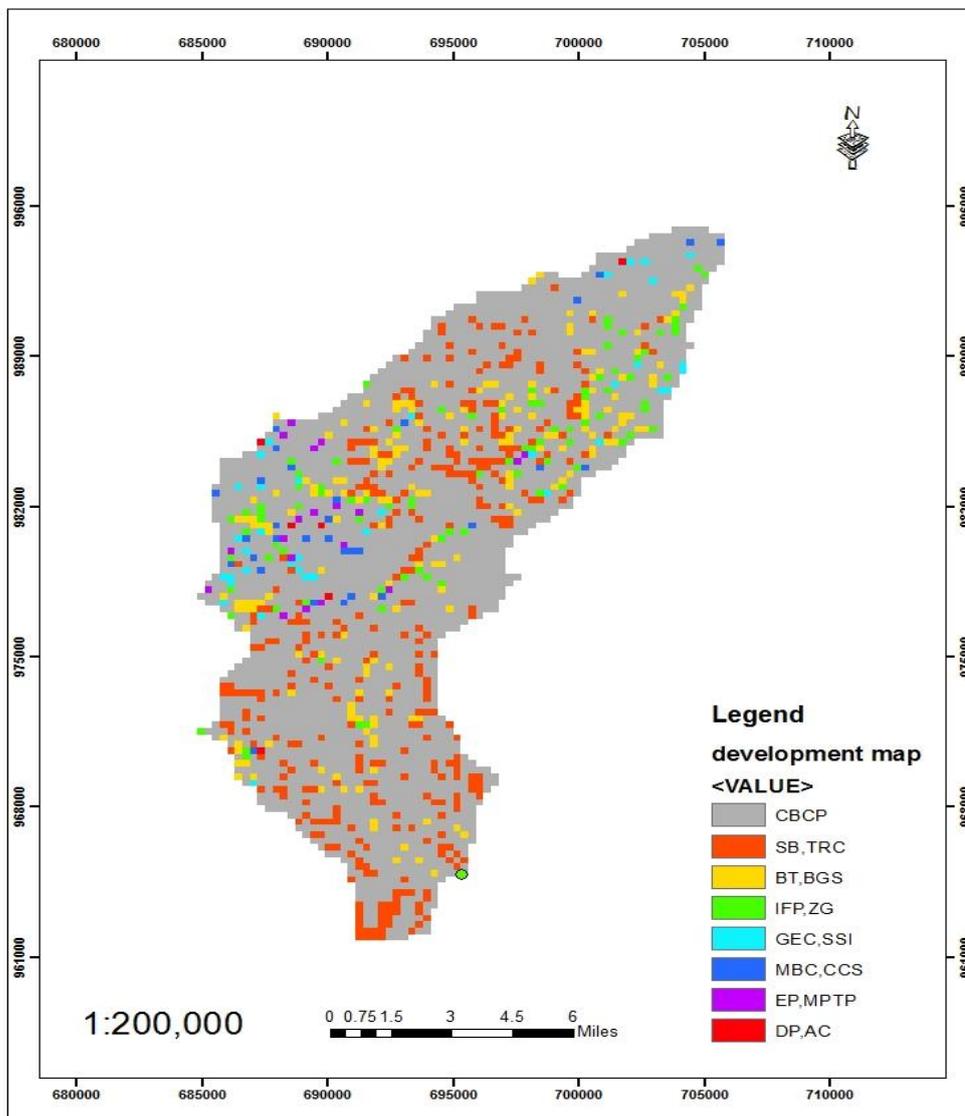
The following roman numbers gives development map legend and the number indicates the ordered of priority .Small roman number refers to high priority /hot spot areas and large numbers refers to low priority. In general, high priority is given to land covers under cultivation

and these land are considers as hot spot area/critical areas prioritized for immediate intervention followed by grazing lands.

Table10-5Legend for Shor SSIP Watershed Development Map

Symbol	Description	Symbol	Description
CBCP	Conservation based cropping practices (Crop rotation, Contour cropping, Alley cropping, Relay cropping)	ZG	Zero Grazing
WW	waterways	SB	Soil Bunds
BGS	Bund with grass strip	TrC	Trench Construction
SSI	Soil Structure Improvement	CCS	Cut and carry system
BT	Bench Terraces	GEC	Gully erosion control
AC	Area cosure	EP	Enrichment plantation
MPTP	multipurpose trees plantation	MBC	Micro-Basin Construction
DP	Demarcation and Protection	IFP	integrated forest management

Figure 10-1: Watershed Development Map of Gura Erbe Watershed



10.3 ACTIVITIES AND SCHEDULE

Sequencing of activities in implementation of watershed management intervention measures should start with prioritization of activities and planned activities should be aligned with suitable period. Hence, selection of appropriate season should be one of the major parts of planning the implementations of intervention measures. The implementation phases will be commenced after preparing detail watershed management to be prepared at manageable size of micro watershed by respective Woredas through employing participatory community based watershed development planning approach.

The time schedule for implementation activities is shown in table 10-2. The table shows that the interventions will be implemented in three years period.

Table 10-2: Implementation Plan and Proposed Activities

NO.	Activity	Unit	Total Plan	plan by year		
				year-1	Year -2	year-3
1	Physical SWC measures					
1.1	Soil Bunds	km	60	20	20	20
1.2	Stone face soil bunds	km	50	15	15	20
1.3	Micro basin	No	300	100	100	100
2	Biological Conservation Measure					
2.1	Establishment of tree, fruit and grass seedling Nurseries	No.	2	1		1
2.2	grass strips	km	70	20	20	30
2.3	compost making and utilization	m ³	10000	3300	3300	3400
2.4	Alley cropping	km	100	20	40	40
3	Livestock development					
3.1	Grazing land improvement and management	Ha	35	10	15	10
3.2	Grass sowing in grazing lands	Ha	35	10	15	10
3.3	forage seeds distribution to the farmers for under sowing	qt	10	2	3	5
4	Alternative Income generating schemes					
4.1	Production of energy saving stove	Group	2	1		1
4.2	Apiculture	Group	2	1		1

5	Alternative Energy technology					
5.1	energy saving stove distribution	HHs	250	50	100	100
5.2	Solar lantern distribution	HHs	250	50	100	100

10.4 INPUT AND COST ESTIMATES

Inputs are resources and equipment, tools and planting materials that are required for implementation of planned activities. List of inputs required for the project are indicated in table 10-2 where us estimated cost is given in Table10-3

Table10- 3: Estimated cost for planned activities

No	Activity	Unit	Total Plan	Work norm	Total PD	Unit cost (Birr)	Total cost
1	Physical SWC measures						
1.1	Soil Bunds	km	60	35pd/km	2100	50	105000
1.2	Stone faced soil bund	km	50	20pd/km	1000	50	50000
1.3	Micro basin	No.	3000	50No/pd	60	50	3000
	Sub Total						158,000
2	Biological Conservation Measure						
2.1	Establishment of tree, fruit and grass seedling Nurseries	No.	2			30000	60000
2.2	grass strips	km	70	10pd/km	700	50	35000
2.3	compost making and utilization	m ³	10000	1pd/m3	10000	50	500,000
2.4	Alley cropping	km	100	10pd/km	1000	50	50000
	Sub Total						645000
3	Livestock development						
3.1	Grazing land improvement and management	Ha	35				
3.2	Grass sowing in grazing lands	Ha	35	10pd/ha	350	50	17500
3.3	forage seeds distribution to the farmers for under sowing	qt	10			1500	15000
	Sub Total						32500
4	Alternative Income generating schemes						
4.1	Production of energy saving stove	Group	2			40000	80000
4.2	Apiculture	Group	2			40000	80000
	Sub Total						160,000
5	Alternative Energy technology						
5.1	energy saving stove distribution	HHs	250			250	65000
5.2	Solar lantern distribution	HHs	250			4500	1,125,000
	Sub Total						1190,000
	GRAND TOTAL						2,185,500

Table 10-4: Cost Estimate for inputs

S.No	Type of inputs	Unit	Quantity	Unit cost (ETB)	Total cost
					(Birr)
1	Tools and equipment				
1.1	Clinometers	No	16	7000	112,000
1.2	Water level (line level	No	20	50	1000
1.3	Altimeter	No	15	5000	75000
1.4	GPS	No	3	7000	21000
1.5	Measuring tape (50mt)	No	40	140	5600
1.6	Pick Axe	No	250	50	125000
1.7	Shovel	No	250	50	125000
1.8	Hoe	No	250	60	150000
1.9	Crow Bar	No	250	100	25000
2	3 finger Hoes	No	10	40	4000
2.1	Watering can	No	10	60	600
2.2	Wheel barrows	No	10	2000	20000
2.3	pruning scissors	No	10	100	1000
2.4	Hammer (5Kg)	No	100	150	15000
2.5	Hand saw	No	10	100	1000
2.6	Compass	No	20	1200	24000
2.7	Polyten tube (Ø 8mm)	qt	10	600	6000
2.8	Polyten tube (Ø 10mm)	qt	10	800	8000
2	Transport				
2.1	Motor Bike	No	4	85000	340,000
Total					1,059,200

Table 10-5: Operational cost

S.No	Item	Total (Birr)
1	Fuel Oils ,Maintenance	1,200,000
2	Stationary	1000000
3	Perdiem	900000
	sub total	3,100,000

Table 10-6: Summary of Total Project Cost

No.	Item	Total (Birr)
1	cost for planned activities	2,185,500
2	Cost of input	1,059,200
3	operational cost	3,100,000
	Grand Total	6,344,700

10.5 BENEFITS EXPECTED

10.5.1 Economic Benefit

Apart from long-term economic and ecological benefits, the target population in the watershed will be benefited from an improved quality of life and community empowerment skills, including women's training, project formulation training and gender awareness.

The benefits of watershed management interventions could be qualitative and quantitative. The quantitative benefits include the gain in economic terms from the implemented measures, which requires the comparison of the total cost incurred to develop a certain measure and the benefit obtained after the measure is being in place.

This involves cost-benefit analysis of the measures. The qualitative benefits involve the benefits that may not be easily or directly quantified in monetary terms. For example, the cooling effect and increase in concentration of oxygen due to plantation of trees in a certain area. However, the quantity of biomass production can be quantified directly. In spite of such differences, cost-benefit analysis of such programs can be made when the analysis is stretched over time. That is, the benefits from watershed management interventions would accrue not so much to the present generation but would be enjoyed more by future generations. Such analysis is not part of the present study. However, the following benefits of watershed management are expected:

- Stabilization or increase in crop or pasture yields.
- Increased income and employment
- Improved livestock production from increased quantity and quality of fodder, for example from grass strips, alley cropping or bund embankments
- Improved supply of fuel wood and construction materials

10.5.2 Social Benefit

The benefits of watershed management interventions will also yield social benefits that can be measured in qualitative and quantitative bases. Some of these include:

- Improvement in water supply owing to increased infiltration of rainfall
- Social respect to women,
- income generation is increased and social value is improved
- Prevention of flooding and siltation from downstream socio-economic infrastructures and reservoir
- Increased value of land etc.

11. IMPLEMENTATION STRATEGIES

In order to improve the productivity of land in the study area, incentive must be provided to the farmers. Supporting the farmer by providing extension service, hand tools and wherever necessary credit etc. can enhance conservation efforts.

In order to ensure successful and sustainable development, need to adopt a holistic and participatory approach in the assessment, upgrading, blending or scaling-up of existing &/or new technologies where integrated natural resource management (i.e. development, utilization and conservation) is ensured. People's livelihoods, socio-cultural, economic and environmental aspects should also be the centerpieces of the overall effort.

11.1 WATERSHED LOGIC RESPECTED

Watershed management requires technical consideration of the orientation of the watershed, in which implementation of development interventions should start from ridge that is the highest part of the watershed to the valley. This will help systematically treat the bigger watershed through treating the smaller ones.

11.2 SMALL AREA BASED APPROACHES

The general understanding should be that the plan covers whole areas of the study area .Thus, starting in small area, such as micro-catchments, sub-watersheds or slope level would be of a great advantage. Land management approaches and practices can also be possible on private plots or groups or communal areas, such as communal forest, communal grazing, etc. and then scaled up gradually to complete the whole study area.

11.3 COST-SHARING

Cost sharing by stakeholders contributes to the sustainability of implemented interventions and help building sense of ownership. Various forms of local contributions are possible based upon social networks and group formation mechanisms. In this regard, those interventions requiring labour need to be implemented by community and investment on those measures and inputs, which cannot be managed by the community, should be made by other agencies.

11.4 PARTICIPATION

Participation tends to build public confidence and improve the public's understanding of development objectives. It provides additional data for planners and policy makers. Public participation is particularly important in rural development, for without the active involvement of the people including identification by them, of the problems that most need tackling and how to deal with them - little can be achieved.

Without participation, there is too great a danger that the strategy will remain a paper plan, possibly leading to coerced efforts at development of marginal benefit to the people of the watershed. The major themes of this strategy have to be discussed with the people so that they can be developed further and implemented by them and for them. A participatory approach is fundamental to sustain real development in the watershed. Detail procedures of participatory planning, implementation and monitoring and evaluation are given in Community Based Participatory Watershed Development Guideline (MoARD, 2005)

11.5 EXTENSION SERVICE AND TRAINING

Conservation extension and education aim to create community awareness. Activities are categorized into demonstrations, production of conservation extension material, study tools and training, audiovisual sources and exhibitions.

Through producing and distributing well planned, organized and well managed extension system faster communication and understanding can be achieved. Extension service is necessary than the material and technical inputs and then extension service to be provided has to get priority. In addition to development and extension inputs, training inputs are equally important for sustainable watershed development. The boosting of staff morale and competence is an essential component in the strategy for conservation-based development. Training and extension provision on the various land management activities needed.

It is suggested that special attention be paid to the training of women; on integrated watershed management activities as well as in general leadership and management. The training and motivation of women leaders and empowerments of woman is important in mobilizing rural women to participate more fully both as actors of development and beneficiaries of out puts.

11.6 RECOGNITION OF THE ROLE OF WOMEN

Women are one of being more affected due to natural resources degradation. They walk long distances to fetch water, to collect firewood, and to collect feed for their livestock. They are also the first victims of mal-nutrition and under nourishment because of food shortages. Therefore, natural resources degradation problems related to land and water will be solved with the participation of women. The role of women in watershed management is significant especially in homestead based interventions and interventions that are directly linked with their day-to-day activities. Therefore, their role should be recognized in all aspects of the implementation and genuine efforts should be made to achieve their involvement in different watershed management activities.

12. MONITORING & EVALUATION

Monitoring and evaluation are on-going activities and are an integral part of project management and implementation and are carried out by the project partners. The main purpose of M & E is providing the responsible organizations with feedback information on which to base their decisions. The monitoring and evaluations of watershed management should be carried out with active participation of stakeholders including target communities, extension staffs, Woreda experts and higher officials. In Monitoring and Evaluation, indicators are necessary to measure achievements that realized through implementation of the planned activities.

After the completion of the appraisal stage, monitoring and evaluation become a major project activity and periodic reports will be the basis for assessing progress, identifying problems, adjusting work plans and keeping stakeholders informed of progresses. Woreda experts and DAs will implement and monitor the project activities continuously and a standardized monitoring plan will contain procedures for considering outputs, project funds, beneficiaries etc.

12.1 MONITORING

Monitoring is a continuous assessment of activity achievements. It allows the responsible body and its partners to assess performance of the planned activities. Specifically, monitoring system helps to check:

- Whether the planned activity is implemented as per schedule and planned resource
- Community participation is ensured maintained in the implementation of the activities;
- Problems are identified and prioritized
- The inputs required for the project implementation are delivered timely

12.2 EVALUATION

Evaluation is a periodical assessment of achievements. The purpose of undertaking evaluation is to review changes as the result of implementation of the planned interventions. Some of the indicators to be used in the evolution are;-

- Changes in natural resources degradation rates
- Changes in improvement of livestock feed supply
- Changes in soil loss rate
- Changes in sediment inflow to downstream areas
- Changes in energy supply to the communities
- Changes in water yields in the watershed area

Changes on knowledge and skills of the communities and GOs staffs

Change income level of the communities participating in the watershed management activities

Changes in the vegetation cover of the area

Changes in the availability of forest resources for various demands

Changes in vegetation cover of the watershed area

13. CONCLUSIONS

Land degradation is a great threat that requires manifold efforts and resources. Success in reducing land degradation requires clear understanding of its causes, impact, and degree associated with climate, soil, water, land cover and socio-economic factors. Therefore, watershed management study is very important for reversing land degradation and for ensuring sustainable watershed management.

Based on the current watershed management study the following conclusions can draw:-

The result of the study indicated that there is moderate to high degree of soil erosion in Gura Erbe watershed

Soil erosion is relatively high on steep slopes where steep lands are used for agriculture.

The annual soil loss estimation for the study area indicates that soil erosion increases with increasing slope percent and with reduction of vegetation cover

- 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 have 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 reservoir 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;
- The population density is high in the watershed Woredas that is due to ever-increasing growth of the population. Therefore; Family Planning Education and provision of the FP medicines is essential to make the population size compatible with the available natural resource and economic growth rate of the region in particular and the country in general;
- 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

- Chopra R, Dhiman RD, Sharma PK (2005). Morphometric analysis of sub-watersheds in Gurdaspur District, Punjab using Remote Sensing and GIS techniques. *J. Indian Soc. Remote Sen.*, 33(4): 531-540.
- EMA & RCMRD-SERVIR AFRICA. 2015. Ethiopia 2008 scheme II Land cover.
- Escabedo J., and Volli C., 1990 land capability classification for soil conservation in Ethiopia, Assistance to soil conservation, A Field document
- 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.
- Ethiopian highlands Reclamation study (EHRS). 1985. Land Use Planning & Regulatory Department, Ministry of Agriculture Food & Agriculture Organization of the United Nations
- Gravelius H (1914). *Grundrifi der gesamten Gewcisserkunde. Band I: Flufikunde (Compendium of Hydrology, vol. I. Rivers, in German)*. Goschen, Berlin, Germany, pp. 179
- Hurni H, 1988. Degradation and conservation of resources in Ethiopian highlands mountain research and development
- Hurni, H., 1985. Erosion-productivity-Conservation system in Ethiopia. IV International conference on soil conservation, Maracay, Venezuela.
- Miller VC (1953). A quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain Area, NR Technical Report 3: Va. and Tenn. Office Naval Research Project.
- MOA .2005 . Community Based Participatory Watershed Development Guide , Ministry of Agriculture, Addis Ababa, Ethiopia
- MOWR.2007. Rift Valley Lakes Basin Integrated Resources Development Master Plan Study Project .
- Strahler AN (1964) Quantitative geomorphology of drainage basins and channel networks: Handbook of applied hydrology. McGraw Hill Book Company, New York, Section 4-76.
- Wischmeier WH and Smith DD, 1978. Predicting Rainfall Erosion Losses - A Guide conservation. US Department of Agriculture: Washington, DC.